science and public affairs

BULLETIN OF THE ATOMIC SCIENTISTS

The Williamstown Summary of Critical Environmental Problems

OCTOBER, 1970

PRICE $1

"We have come here with the memories fresh in our minds of the past ten years — the disappointment, the deep divisions, the moments of danger and almost despair, but also the frequent evidence that the positive spirit of man can cope with the challenge of living together at peace in our interdependent world." Dag Hammarskjold, United Nations Tenth Anniversary

Frustration, anger and despair are not the best milieu for problem solving. Raw emotions evoke value systems that history has proven to be false. Thus, objectivity and humility are still the best approaches to problem solving. Without them science would never have triumphed where previous 'philosophies' have failed.

EDM

EMBOSOGRAPH DISPLAY MFG. CO. CHICAGO, ILLINOIS 60614

Copyrighted material

science and public affairs

BULLETIN OF THE ATOMIC SCIENTISTS

Founded in 1945 by Hyman H. Goldsmith and Eugene Rabinowitch

OCTOBER 1970 • VOLUME XXVI • NUMBER 8

Published by the Educational Foundation for Nuclear Science with the cooperation of the Adlai Stevenson Institute of International Affairs. The assistance of the Center for the Study of Science and Society, State University of New York, Albany is appreciatively acknowledged. The Bulletin Clock, symbol of the threat of nuclear doomsday hovering over mankind, stands at ten minutes to Midnight.

EDITORIAL STAFF

Editor-in-Chief, Eugene Rabinowitch; Managing Editor, Richard S. Lewis; Manuscript Editor, Ruth Grodzins; Make-Up Editor, Nat Laddin; Book Editor, Jane Wilson; Production Editor, Frances Gendlin; Copy Editor, Susan Cullen. Consultants: Editorial, Ruth Adams, Victor Rabinowitch; Art, Martyl.

CIRCULATION STAFF

Manager, Dana Powell; Assistant, Willa Sykes; Promotion, Bernard Mazel; Advertising, Michal Rooney.

EDITORIAL BOARD

Robert Gomer
Robert Haselkorn
David Inglis
Hans J. Morgenthau
Richard Preston
Stuart Rice
Theodore W. Schultz
Edward Shils
Mary Simpson
Bernard I. Spinrad

BOARD OF DIRECTORS

Robert M. Adams
Bernard Feld
Robert Gomer
Harry Kalven, Jr.
Carl Kaysen
Franklin Long
Eugene H. McLaren
Donald H. Miller, Jr.
Eugene Rabinowitch
Stuart Rice
John T. Wilson
Hans Zeisel

Walter J. Blum, **Legal Counsel**
William Swartz, **Financial Counsel**

BOARD OF SPONSORS

Hans A. Bethe, **Chairman**

Robert F. Bacher
Detlev W. Bronk
E. U. Condon
F. Daniels
Bentley Glass
S. A. Goudsmit
T. R. Hogness
F. W. Loomis
Philip M. Morse
Linus Pauling
I. I. Rabi
Julian Schwinger
Frederick Seitz
John A. Simpson
Cyril S. Smith
Edward Teller
Harold C. Urey
V. F. Weisskopf
Hugh C. Wolfe
Sewall Wright
J. R. Zacharias

Samuel K. Allison (1900-1965)
A. H. Compton (1892-1962)
Albert Einstein (1879-1955)
James Franck (1883-1964)
H. J. Muller (1890-1967)
J. Robert Oppenheimer (1904-1967)
G. B. Pegram (1876-1958)
Leo Szilard (1898-1964)

Editorial and advertising correspondence should be addressed to Bulletin of the Atomic Scientists, 935 E. 60th St., Chicago, Ill. 60637. Manuscripts must be submitted in duplicate and accompanied by a self-addressed envelope and return postage.

Subscription correspondence should be addressed to Bulletin of the Atomic Scientists, Circulation Department, 935 E. 60th St., Chicago, Ill. 60637. Please allow 5 weeks for change of address. Include your old address as well as your new address and, if possible, an address label from a recent issue.

ARTICLES

2 On Killing Members of One's Own Species .... *Konrad Lorenz*
6 Verification of Nuclear Arms Limitations: An Analysis .... *Herbert Scoville, Jr.*
12 Paris, Pretoria, Peking—Proliferation? .... *George H. Quester*

REPORTS

ENVIRONMENTAL DISASTER - ACTS OF NATURE AND MAN:

17 The Peru Earthquake: A Special Study .... *U.S. Department of the Interior*
20 Science and the Quality of Our Environment .... *W. T. Pecora*
24 The Williamstown Study of Critical Environmental Problems .... *SCEP Summary*
31 Auto Exhaust, Pollution and Weather Patterns .... *Vincent J. Schaefer*
34 A Biologist Explains: Why We Must Plan Now to Protect the Arctic .... *L. C. Bliss*
39 Environmental Side Effects of Energy Production .. *Donald F. Anthrop*

COMMENT

42 The Dual Challenge of Health and Hunger: A Global Crisis .... *Georg A. Borgstrom*

COMMUNICATIONS

47 Ocean Science .... *Milton Leitenberg*
48 Laboratory Graduate School .... *Michael J. Moravcsik*
48 Tektite .... *Richard N. Rigby, Jr.*
49 Mumbling and Fumbling — or Lying? .... *Ann E. Berthoff*

CREDITS

Cover photo, courtesy Argonne National Laboratory; Cover design by Jack Jordan. Other photos: p. 2, Photo Contest Winner, October, Kenneth McAllister; pp. 17, 21, 23, U.S. Department of the Interior; p. 27, Boeing Company; p. 41, Peter Moldauer; pp. 43, 45, CARE, Inc.; p. 52, John G. Shedd Aquarium. Artists in this issue: Harris, pp. 11, 15, 50; Jordan, p. 36.

BULLETIN OF THE ATOMIC SCIENTISTS, *Volume XXVI, Number 8. Published monthly ten times a year (suspending publication in July and August). Second class postage paid at Stevens Point, Wisconsin, and at additional mailing offices. Subscription rates: U.S.—1 year, $8.50; 2 years, $14.50; 3 years, $18. Canada and Pan American Union—1 year, $9; 2 years, $15.50; 3 years, $19.50. Other countries—1 year, $9.50; 2 years, $16.50; 3 years, $21.*

Copyright 1970 by the Educational Foundation for Nuclear Science,

935 E. 60th Street, Chicago, Illinois 60637.

This One
44YN-GEA-2W6N

KONRAD LORENZ

On Killing Members of One's Own Species

Copyrighted material

"Science has been responsible for our progress, but part of what it has given us are the very weapons that today threaten us with self-annihilation. It is high time for science to explore the nature of this most burning threat. Until now—not too sucessfully—only the moralists have tried their hand. Let us apply our scientific curiosity to the task of how we can strengthen the instinctual inhibitions that must help us if we are to avert destruction."

The zoologist Konrad Lorenz is director at the Max-Planck-Institut, Seewiesen, Germany. This article, under the title "Uber das Toten von Artgenossen," first appeared in the 1955 Jahrbuch der Max-Planck-Gesellschaft. It is one of the contributories to Lorenz's book "On Aggression," published in 1966. The article appears here for the first time in English, translated with the author by Hans Zeisel, professor at the University of Chicago Law School.

Killing members of one's own kind, whether animal or human, is behavior ill-suited to the preservation of the species.

Every organism, the individual as well as the species, is a system in which all parts affect each other. The system is regulatory in the sense that it tends to preserve itself: when disturbed, it returns to its prior equilibirum. This self-regulating characteristic of all living organisms seems to be essential for survival since orderly systems are generally improbable and, according to the second law of thermodynamics, are destined for disorder and death. The development of everything organic toward order, seemingly contradicting the laws of probability — and yet without any infraction — forms one of the basic problems of biology.

Every organic system is the result of a historic development, much in accord with Goethe's definition of development as the differentiation and subordination of the parts. As an organism reaches a higher state of development, the division of labor among its parts becomes more and more differentiated, and they become more and more dependent upon each other. One can cut a hydra into minute parts, and each of these parts can live on; with a worm, at least some segments must remain intact if life is to continue; but a vertebrate can not even survive severance of its head.

The further this differentiation and subordination of the parts develops, the more miraculous and purposeful the harmony of that cooperation appears. This "building plan" represents for Jacob von Uexkull, the great vitalist, the unexplorable miracle, closely related to the platonic idea. But historical, that is, biological, investigation of the process of this development reveals it as somewhat less purposeful, although not less miraculous. A living organism in its total structure never resembles a modern building planned by a circumspect architect long before it is built. It is, rather, like one of those rambling farm houses where the setttler first built one small part and later, as time and resources permitted, added other units. Many parts in such a building will have their functions reassigned. The original living room may become the shed, and some parts may even lie unused, interfering with the rest simply because it was never possible to tear the place down and build it over again. These strong limitations on destroying what has become biologically useless is for the phylogeneticist a great help, because it puts on every living organism the stamp of history.

When some fishes became terrestrial vertebrates, the gills — a structure so wonderfully adapted for breathing water — lost their function, although some parts were being used to support tongue and larynx and were accordingly reshaped. The first gill cleft, which by chance lies closest to the shock-sensitive labyrinth, can feed air waves into it and is, therefore, preserved; the existing passage became the eustachian tube. But some structural details of the water animals were retained which are in no way helpful to the land animal.

The new breathing organ, the lungs, was simply derived from one of the arteries of the gill arches; the lung vein was developed in a similar manner. The principle — to build the new structure as inexpensively as possible from available materials — has led to a circulation system which, because of the mixing of arterial and venous blood, is much inferior to that of the ancestral fish. Not until bird and mammal arrive does the constructive revision reach the stage where arterial and venous blood again become separated.

NO MASTER PLAN

We must free ourselves entirely from the idea that any organic development must have a good purpose. In addition to everything that has a positive survival value, there exists everything that is not so detrimental as to cause the annihilation of the species. No wise master plan rules the development of the species. Rather it progresses under the pressure of merciless selection, and each species must see to its survival. This is true also for us, homo sapiens, who at present appear to be particularly rich in traits not exactly helpful to the preservation of the species.

The vitalists have been blinded to the existence of innumerable detrimental traits by their deep, and by itself lovable, veneration of organic creation. Uexkull denies, quite consistently, that there are traits in the architectural plan of the living organism merely carried over as remnants of this historical process. Although any student of phylogenetic development cannot help seeing these vestigial traits, Uexkull simply ignores phylogenesis as a whole. It is anathema to him that simple conservatism could preserve such clearly deterimental traits.

In reality, the "purposeful" can be meaningfully defined only if one recognizes both the fact of historical phylogeny and the existence of useless and even detrimental traits as the unavoidable result of the trial and error mechanism of organic evolution. The question "What for?"

has a meaningful answer only where evolution has taken place. The question "To what purpose do physical bodies attract each other?" is clearly meaningless. But the question "Why does the cat have claws?" easily suggests the answer, "To catch mice with."

But this indication of purpose is a direction sign which we put up only after the fact, in retrospect, of the evolutionary process. Any existing product of the process of natural selection has by definition a purposeful structure, otherwise it would not exist. We see only the results of the successful experiments. And because "nil in intellecto quod non ante fuerat in senso," we believe all too easily that there never have been any failures, that there never can be any — although our own species is in acute danger of becoming one.

FUNCTION CRUCIAL

For the scientist who thinks in historical and causal-analytical terms, the question "Why does the cat have claws?" means only "In the service of which function of this species [cats] was this particular trait developed?" Thus, the question "For what purpose?" is only then, but then always, justified with respect to a complex and harmonious organism, when we can exclude with some confidence its development through pure chance events. It makes no sense to ask "Why" some chickens are white and some brown, unless one has first determined whether this distinction had any function in the preservation of the species. Suppose, however, I am dissecting, for the first time, a woodpecker and discover the immensely specialized tongue mechanism with its elastic tongue bone that enables the woodpecker to extrude its tongue by many times the length of its own head. If in this case I assumed that only a very powerful survival function could have moved the selective process toward such an improbable construction, the chances of my being in error would be immeasurably small.

But it can happen that selection produces a trait which, in other respects, is detrimental to the species. The question as to why the bulldog has such a short nose and a ring-tail appears to be, offhand, meaningless, if not funny. But from the bulldog's point of view, there is a perfectly sensible answer: the purpose of these traits is to secure for him a prize at the dog show, without which the chances of the bulldog's survival as a species would be zero. What factors determine the course of selection matters little; it may be a circumstance in the natural habitat which gives the pointed claws to the cat, or it may be a silly fashion which determines the properties a dog should possess. The selective factors can become even sillier and more short-sighted: note the idiosyncrasies of the female which determine her choice of a spouse.

The arm wings of the male argus pheasant, for instance, have become the organ which sexually stimulates the watching female. The greater the stimulus the stronger the innate response, with the result that it is the pheasant with the largest arm wings that will be chosen by the hen. Wherever we find in birds, or in bonefishes, such extreme differentiations of the male mating organs, the choice of the mating partner rests exclusively with the female. But the argus pheasant's large arm wings are clearly harmful to his survival in the outside world — he can hardly fly any more. One can easily think of a hundred different possibilities for producing an effective mating stimulus that would not require destroying the pheasant's ability to fly, which is surely useful for the preservation of the species. On the satyrhen, for instance, a harmless inflatable red pouch on the esophagus sends out the mating stimulus. There exists a large number of well-established cases where sexual competition among members of the species has led to otherwise completely useless developments. Think of the antlers of the deer, particularly the antlers of the extinct Irish elk which developed through mating fights. Utterly bizarre results are often achieved. As my teacher Heinroth used to put it: "Next to the arm wings of the argus pheasant, modern man's pace of work is the silliest product of intraspecific selection." It is no innate drive, but only the competitive organization of our society which drives us toward high blood pressure and nervous breakdown. Only by seeing this clearly can we appreciate the thoughtlessness of our civilization.

Nevertheless, I believe there is a still costlier by-product of our intraspecific selection, namely, the evil system of man's aggressive instincts and his ever increasing armaments. Ever since homo sapiens reached the stage where the large beasts of prey and the climate ceased to be major obstacles to his increase in numbers and were replaced by competition for space with hostile neighbors, the selective pressure for the development of arms and military "virtues" became strong. The aggressive instincts, which up to then had played only a modest role, were gradually rewarded with special selection premiums. We must visualize these ancient hordes much like some tribes of present New Guinea who live in a constant state of war, with headhunting and cannibalism. But at the same time, there probably developed a selection premium for the diminution of all those individual forces that tend to inhibit some social animals and, which fortunately, still prevent some men from killing members of their own kind. It is these innate inhibitions, I believe, which are damaged by the dark past of humanity and which still could be of crucial importance in our present human situation. It may be worthwhile, therefore, to explore the conditions under which these inhibitions can thrive. It might help to save us from self-destruction.

HIGH SELECTION

The first thing to appreciate is that any animal able to kill another animal its own size requires a very special mechanism to keep it from killing members of its own species. This is true primarily for carnivores, but it is also true for any adequately armed animal. The species-preserving purpose of such a restraint mechanism is as obvious as is the harmfulness of its absence. Clearly, a very high selection pressure is needed to produce such a mechanism, because an animal whose species can survive without it does not have it.

To most types of bonefish, with their vast reproduction rate, it matters little whether the adults eat, in addition to innumerable other fish, the young ones of their own species. Neither does the solitary beast of prey, which lives in isolation and hardly ever meets a member of its own species, need any such restraint. The pike, for which both these considerations pertain, can even afford to prefer little pike to other fish without risking the extinction of its species. I myself once found a pike in a pike in a pike. Moderately armed species, well equipped to flee before hunting beasts of prey, usually show little hesitation in killing their own type. A dove is so fast that it can often escape a pursuing game falcon; and a hare can elude the wolf. These species therefore can easily persist even without the killing restraint mechanism. I am sorry to destroy a cherished illusion, but Picasso's famous symbol of peace is anything but a model for how we humans should treat each other. I have often told the story of how I once left two doves fighting in their cage, confident that they would not harm each other. But I later found one completely scalped, lying on the floor, while the other, utterly exhausted, continued to tear into the mangled back of its companion. Hare, deer, and many other "harmless" animals behave quite similarly.

The lowest vertebrates, known to have specific repressions that prevent them from killing their own species, are certain bonefishes which — like the stickleback; the labyrinth fish; some catfish, but especially a certain perch; the cichlids — provide elaborate parental care. These are small but very martial predatory fish which will hunt anything alive, except their own offspring for which they care like the mother hen for its little chickens. With some species, primitive in this respect, like Nannacara and Apistogramma, the problem of how to keep them from devouring their offspring is solved most simply: during the period of parental care they lose their appetite and eat almost nothing. Also the stimuli which release the breeding mechanisms are simple and show only little differentiation. Anything that crawls on the ground and gives up carbon dioxide — for instance, a clump of tubifex, the tube worm used to feed fish — triggers the movements through which these fish fan fresh, oxygen-rich water toward their eggs and the young offspring yet unable to move. On the other hand, the movement to lead the offspring is released through a mechanism which reacts with little selectivity: any multitude of small organisms cruising through the water in dense clusters will bring this release about.

If too many water fleas (Daphnia), used as fish food, are put into the tank, the female of many mini-cichlids, especially Nannacara, take on breeding colors and begin to make leadership movements. At the same time they become incapable of eating even a single one of the Daphnia, as if they were their own offspring.

Professor Konrad Lorenz

However, the larger cichlids, those with more specialized breeding reactions, are very well able to distinguish their offspring not only from crustaceans and worms, but even from the young of a closely related species.

According to observations by G. P. Baerends, these eating inhibitions appear to be bound up with personal experiences. Cichlids who at their first breeding experience were made to breed eggs of another species henceforth wanted to care for that species only, and showed no hesitation in eating their own offspring as soon as they had reached the free-swimming stage. The inhibition against devouring one's offspring seems to be governed by a sensitive, easily disturbed mechanism. Most cichlids during this breeding time react to minor disturbances or invasions by eating their young ones, often all of them at once. This always happens if the breeding pair, for reasons to be discussed presently, begin to fight. In any event, we are sure that the young fish emit stimuli apt to release the eating reaction of the parents, and this reaction is kept under control only through a highly specialized mechanism. Feeding is by no means the only, and not even the most frequent, stimulus for killing a member of one's own species. Many vertebrates, when they chance on an unfamiliar member of their own species, exhibit fighting reactions of greater or lesser intensity. Only the amphibians seem to lack altogether such aggressiveness towards members of their own species; it is a reaction which is almost always seen in bonefish, reptiles, birds and mammals.

Are these reactions of any positive value for the preservation of the species? Ecologists and ethologists have no doubt that they are. Among animals that do not live in groups, intraspecific aggression plays an important ecological role in distributing the animals evenly over available living space. With breeding animals, such as the cichlids, the life expectancy of the new generation depends very directly on the fighting ability and fighting fervor of the parents. This is undoubtedly why there is such a high premium on the procedure that selects the strongest couple for the fought-over territory, and assures that the strongest male wins the fought-over female. Even animals with very highly developed group life seldom show a reduction of this aggressive instinctual behavior, which often proves to be an indispensable link in the motivational system that forms the very foundation of their group life.

It will help us to understand these problems better if we look at a few concrete examples of how aggression is built into a system of social behavior, and how it is usually kept from degenerating into behavior

(Continued on page 51)

HERBERT SCOVILLE, JR.

Verification of Nuclear Arms Limitations: An Analysis

Once an arms limitation agreement is made, how does each side know the other is keeping it? "In the light of existing national verification capabilities, the large numbers of weapons on each side and the insensitivity of each side's deterrent to relatively large force changes," says Dr. Scoville, "I am confident that an agreement can be designed which would significantly limit strategic armaments and in fact increase real security." The author, director of the arms control program of the Carnegie Endowment for International Peace, was formerly technical director of the Armed Forces Special Weapons Project, and assistant director for science and technology of the U.S. Arms Control and Disarmament Agency. This analysis was presented to the Senate Foreign Relations Committee's subcommittee on Arms Control, International Law and Organization April 13, 1970.

Verification has been a stumbling block in negotiating almost all arms control agreements since World War II. The closed society in the Soviet Union has always fed fears in this country that the Soviets might use an arms control agreement to restrict a U.S. weapons program while allowing the Russians to continue their program clandestinely to the point of achieving a military advantage. A classic and perhaps overemphasized example of this problem has been in the negotiation of a comprehensive test ban treaty. The United States has always feared that the Soviets could derive significant military gains by underground tests which could not be distinguished from earthquakes and has sought inspections to clarify the nature of the seismic events. The Soviet Union resisted this desire as a threat to their society, and as a consequence no agreement on banning underground nuclear tests has yet been achieved.

In evaluating the adequacy of any verification procedures, it is important to emphasize that it is not necessary to be able to detect every possible violation but only to have the ability to detect those which could significantly affect U.S. security. If a nation believes that there is a risk of the violation being discovered, it is unlikely that it would take that risk unless the violation provided a significant gain. Cheating on an ICBM (inter-continental ballistic missile) launcher freeze by secretly building a dozen or even a hundred missile silos makes no sense when both nations already have more than a thousand missiles.

Any arms limitation, together with its means of verification, should also be designed to avoid continual alarms that violations were occurring, since if these occurred frequently the value of the agreement would be greatly reduced. Fears of minor infractions of the agreement should not be allowed to become a source of major international incidents. This can be avoided as much by proper phrasing of the agreement as by the mechanics of verification itself.

In general, arms limitation verification procedures are divided into two categories. The first is known as "national" or "unilateral" verification techniques, which do not require any agreements for inspection within the boundaries of another nation. The second category is termed "on-site inspections," in which a nation would agree to allow nationals of another country to inspect within its territories to determine whether a violation had occurred. Intermediate to these two categories would be those situations in which both sides agreed to conduct their operations so as to facilitate verification by national means.

ANTARCTIC TREATY

Only in the case of the Antarctic Treaty has the Soviet Union allowed the use of on-site inspections to verify compliance with the treaty. At one time Chairman Khrushchev agreed in principle to three on-site inspections per year within the Soviet Union to monitor a comprehensive test ban treaty, but at that time the U.S. did not believe three a sufficiently large number. Since then the Soviet Union has withdrawn that offer. All other arms control agreements which have been negotiated have relied primarily on national means of verification. The Limited Test Ban Treaty is monitored by such national systems, and all countries have a high degree of confidence that significant violations are not occurring. The same is true of the undertaking in the Outer Space Treaty, not to place nuclear weapons in orbit around the earth. General Wheeler in testifying in support of that obligation said that he favored reliance on national means since he did not believe that the Soviet Union could, without U.S. knowledge, violate this provision so as to obtain a significant military advantage.

In this connection, it is interesting

to consider briefly the history of the Limited Test Ban Treaty. This treaty is verified by highly sophisticated scientific national techniques, and I believe that all countries have a high confidence that any significant violation of this treaty could be detected. Nevertheless on several occasions since the treaty came into effect, radioactive material from underground tests has been detected outside the boundaries of the country in which the tests were held. This could be considered a technical violation since the treaty bans tests which cause radioactive debris to be present outside the territorial limits of the state under whose control the explosion is conducted. While these occasions have resulted in exchanges of notes and requests for explanation, both the U.S. and the Soviet governments have recognized that the events did not threaten either nation's security nor did they significantly increase the health hazards throughout the world. As a consequence neither nation has made a major international incident out of these possible technical infractions. However it is an example of where the wording of the treaty may have been sufficiently ambiguous as to permit a difference of views as to whether a violation had occurred even though the verification procedures were quite satisfactory. Such ambiguities in treaty language should be avoided to the maximum extent possible, without, however, at the same time incorporating so many technical details that the treaty could become inoperable as a result of unforeseen scientific developments.

Verification is not limited to arms control agreements but is also an important factor in our everyday unilateral national security planning. Decisions that are made on ICBM force levels, on whether to deploy an ABM (anti-ballistic missile), or whether to develop MIRVs (multiple independently targeted re-entry vehicles) or other penetration aids to overcome a Soviet ABM are all based on the best information nationally available on Soviet armament programs. In such day-to-day unilateral planning it is not enough just to know that a missile has been deployed. One must also know the characteristics of that missile and have some basis for estimating the quantity and the timing of the total deployment program. Thus, the information required for unilateral planning is much more difficult to obtain than that required to monitor an arms limitation agreement where information that a single missile launcher had been added to the force would be all that might be required in order to verify that a freeze was not being abided by.

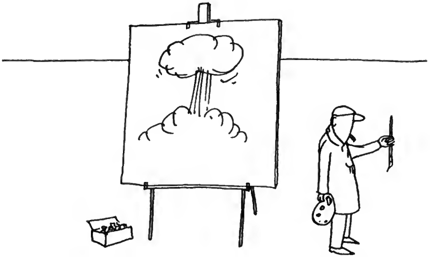
MOBILE ICBMS

A good example of where it would be much easier to verify satisfactorily an arms control agreement than the size of the force for unilateral planning would be in the area of mobile ICBMs. If, as a result of SALT (Strategic Arms Limitation Talks), it were agreed that mobile ICBMs would be totally banned, then the ability to detect the deployment of even a single such missile would be sufficient to verify whether the agreement was being abided by. It would not be necessary to count precisely the number of mobile missiles deployed, which might be very difficult unless one had instantaneous observation of the entire Soviet Union, to avoid confusion if the missiles were moved from one place to another between observations. On the other hand, in order to determine for our unilateral force planning whether a Soviet mobile ICBM force, which had not been restricted by an agreement, posed a threat, one would need to know the size of such a force. This might be very difficult to accomplish with suitable reliability.

This example raises another point which should be kept in mind in evaluating the adequacy of verification capabilities for any arms control agreement. First, one must always evaluate the relative risk from a possible violation against the risk which might exist if no arms control agreement were achieved. For example, the risk of an undetected Soviet violation of a ban on mobile ICBMs, which the United States has no plans to deploy, would be far less than the risk of no agreement which allowed the Soviets to build up a force of undeterminable size and characteristics. Further, when programs are proceeding without any restrictions, information on the nature of new developments and deployments can often be confusing and misleading and, consequently, produce less than optimal unilateral U.S. weapons decisions.

Finally, adequate verification of limitations on strategic arms is greatly simplified at this time by the fact that both sides now have such large forces of survivable strategic weapons that any clandestine program in violation of a treaty would have to be very great before it could threaten our national security. Not only are the numbers large but there are also several different types of systems available in our assured destruction force, i.e., submarine launched missiles, hardened land-based missiles and intercontinental bombers, so that a sudden unexpected threat to one system will not jeopardize the entire second strike force. Deterrence can be maintained by both sides despite large changes, either qualitative, or quantitative, in the force structure of either side. For example, although the Soviets have more than trebled their missile force in the last five years, they are still a long way from being able to prevent the United States from inflicting widespread and unacceptable devastation on the Soviet Union in a retaliatory attack. Even if in the highly unlikely event that the Soviets succeeded in secretly developing a MIRVed missile force which could destroy all U.S. land-based missiles, the United States would still have a force of 41 Polaris submarines, each with 16 missiles, only a small fraction of which would be required to devastate the Soviet Union.

This was, however, not the case in 1960 when the deterrent force relied almost entirely on vulnerable bombers and had only a few or no ICBMs. Then, even a small increment to these missile forces would have had very significant military consequences. Moreover, we are now much better off technically to verify by national means the size and characteristics of the opposing strategic forces than in the 1950s. While it is not appropriate for me to discuss our technical capabilities in an open hearing, I am sure it is no secret that our capabilities have improved markedly in the last ten



years. Had they not so improved, it would not have been possible for Secretaries MacNamara, Clifford and Laird to report year after year with high confidence on the size of the Soviet ICBM force, submarine force and ABMs.

DETECTING VIOLATIONS

Any nation which attempts to violate any arms limitation agreement on a scale sufficient to obtain a significant military advantage will run some risk of being detected. Defection by disillusioned personnel, or disclosure of the violation by an agent, can never be ruled out for even the most secret program. However, such sources of information are unreliable and cannot be counted on by the United States when its vital security interests are at stake. Therefore since verification capabilities vary greatly for different phases of the weapons development cycle, arms limitation agreements should be designed to emphasize those phases which are at the same time easy to monitor and critical to security.

Research and development, while still in the laboratory phase, could rarely be reliably detected either by any type of national observation system or by any acceptable on-site inspection scheme. Thus it is only when the development reaches the testing phase that strategic weapons programs become observable and provide opportunities to verify restrictions on development of new systems. Before most offensive missile systems can be reliably deployed, they require extensive tests at long range so that they can be monitored beyond the borders of the testing nation. The United States has been able to observe Soviet ICBM tests consistently since their program began in 1957. Not only have successive Secretaries of Defense reported on the number of missile firings but in many cases on the characteristics of the weapons being developed. While defensive interceptor missiles do not travel such long distances, the high-powered radars which track the incoming warhead and guide the interceptors emit radio waves which can often be discernible at remote locations. Since much testing is relatively easily verifiable, it is frequently a good point in the weapons cycle to start applying limitations.

The production of strategic weapons is again more difficult to observe. Many components can be produced in small buildings and even a complete missile could be assembled in structures which might not be easily identifiable. National means of verification might locate many suspicious structures, and frequent on-site inspections might be required to provide sufficient confidence that violations of a ban on production were not occurring. For ABM systems it would be even more difficult since the missiles are smaller and the electronic components for the radars would be indistinguishable from those required for other purposes until they were finally assembled in the deployed radar. The one exception would be the production of missile launching submarines which employ for their construction large and fairly easily identifiable shipyard facilities.

Finally, deployment, the last stage in the weapons cycle; it is easy to observe deployment and determine changes in the number of operationally deployed systems. To simplify the verification it is usually best to have a complete ban or to freeze the number at existing levels rather than agreeing on a fixed number of items. After a freeze has been achieved, then the levels can be reduced by agreed numbers.

DIFFICULTIES

It is often not so easy to determine the characteristics of the systems deployed, since many of these are independent of the external configuration of the hardware. Once missiles with certain capabilities were demonstrated and proven in testing, particularly if troop training were observed, one must assume that they could be deployed. However, it will frequently be impossible to know how many have been incorporated in the force and what will be their real operational capability. It would, for example, be difficult to verify with high confidence whether a new type of missile was being substituted for an existing one or whether improvements were being made to existing systems. Therefore, limitations on deployment should emphasize numbers of weapons rather than weapon characteristics.

In order to evaluate the ability to verify deployment limitations, it is necessary to look at each individual strategic weapons system. For the purpose of discussion today, I have concentrated on those systems which would be most critical in a freeze on strategic offensive and defensive weapons.

Fixed land-based ICBMs require extensive launch site construction in order to provide the necessary hardening to make them resistant to blast from a nuclear explosion. This construction requires many months, and therefore ample time is available to permit its detection. In presenting his Fiscal Year 1971 Defense Program, Secretary Laird has reported with great precision the numbers of such Soviet launchers, both operational and their rate of construction, each year since 1966. While in theory it might be possible to build clandestinely at great cost in time and money a few additional launchers using elaborate camouflage techniques, such a violation would have no effect on U.S. security since they would be an insignificant addition to the already large existing forces of more than a thousand ICBMs on both sides. Therefore, a limitation on numbers of ICBM launchers could be adequately verified by national means without the need for any supplementary procedures.

Mobile land-based missiles would be more difficult to monitor, but even these require logistic support which would be difficult to conceal. This would be particularly true in the Soviet Union, where the road system is limited and the rail system well known. However, if large numbers were already deployed, it might be hard to obtain a reliable count of the number of such missiles since the missiles might be moved between observations. If deployment were nonexistent or small at the time the agreement was reached, then a large new deployment would become apparent. Therefore, a total ban on deployment of such systems would be preferable, since the detection of even one would constitute a violation. This country has not developed or deployed any mobile ICBMs, and there are no reliable reports of Soviet deployment of either mobile ICBMs or IRBMs (intermediate-range ballistic missiles), although the Russians have displayed missiles in the Moscow parades which they claim to be such. It is highly unlikely that the Soviets could secretly deploy the many hundreds of mobile ICBMs which would be required to affect the present strategic balance; but the sooner a ban took effect the easier the verification.

SUBMARINE MISSILES

Submarines which have large numbers of long range missiles and which can operate for protracted periods at long distances from their home ports require large and distinctive facilities for their construction. Secretary Laird has reported in his FY-71 Defense Program that the Soviets can accommodate 12 complete hulls at two different shipyards. After the submarines are launched they require many months for fitting out, during all of which they are subject to observation. To have a reliable operational capability they must be shaken down and cruise in the open oceans. Secretary Laird, like his predecessors, has on several occasions reported with confidence the numbers of existing Soviet submarine-launched ballistic missiles (SLBMs). Again, for the Soviets to increase their present relatively small —but rapidly growing—SLBM force, without U.S. knowledge, to a point where it could significantly affect U.S. security would not seem possible. Therefore a ban on construction of new ballistic missile submarines could be verified by national means.

MIRVS

So far I have addressed only the numbers of missiles or their launching platforms; the number of nuclear warheads within a given missile is another thing. Since a single large warhead can be replaced, without changing the external configuration of the missile, by several smaller warheads either with or without a capability to be individually targeted —MIRVs or MRV (multiple reentry vehicles)—it is hard to visualize how the U.S. could verify by national means whether a deployed missile has or has not multiple warheads. In fact, even on-site inspection to make this determination would be difficult. It would require the right to inspect any deployed missile including those on submarines, on sufficiently short notice to prevent substitution of the reentry vehicle. The inspection would require access into the interior of the reentry vehicle or, at the very least, the use at close range of some scientific technique such as x-rays to determine the number of warheads present. Such inspection would almost certainly not be acceptable to the Soviet Union. If the Soviets required similar inspection to verify that the United States was not secretly deploying MIRVs, it is doubtful that the United States could accept it.

Therefore, if MIRVs are to be controlled, every effort should be made to limit testing as well as deployment. At the present time, neither the United States nor the Soviet Union have fully developed and tested a MIRV system with sufficient accuracy and reliability to provide a first strike capability. The Soviets began testing MRVs on the SS-9 in August 1968, and President Nixon in the summer of 1969 stated that the "footprint" of the Russian MRV indicates that they may happen to fall in a pattern comparable to the area covered by a complex of three Minuteman sites. However, as Dr. John Foster, Director of Defense Research and Engineering, stated on February 24, 1970, the Soviets "have not demonstrated to us the flexibility necessary to target each warhead at a different Minuteman silo." All Minuteman sites do not have the same spacing so that the Soviets would require the ability to vary the footprint reliably and accurately if they were to have a capability to wipe out the entire Minuteman force.

MIRV DEPLOYMENT

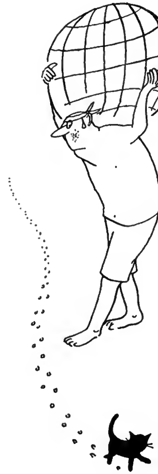
The United States started a two-year program to test first generation MIRVs for the Poseidon and Minuteman III missiles also in August 1968, and DOD officials have announced that the Minuteman III will begin to be fielded in June 1970 and the Poseidon become operational in January 1971. While U.S. officials have emphasized that the accuracy-yield combination of these first MIRVs will not be sufficient to provide a first strike counterforce capability, the Soviets may nevertheless be concerned that the first U.S. systems might have such a capability. Fortunately, the Soviets should be able to satisfy themselves that the United States was not deploying MIRVs in violation of a ban on deployment, since it is hard to conceive how the United States, with its open society, could place MIRVs in a large part of its force without detection. Certainly we should not prejudge the decision for the Soviets and conclude that controls on MIRVs are unverifiable because the U.S. program has proceeded too far. There is still time, but maybe only a little, to prevent deployment of MIRVs if a ban on testing and deployment can be achieved soon.

What are the opportunities for the United States to verify a ban on MIRV and MRV testing? (MRV testing would probably also have to be banned to be confident that these were not confused with MIRVs.) Since the type of MIRV which could threaten the fixed land-based missile force is one which has a very high capability for destroying hardened ICBM sites, i.e., a reliable MIRV with high accuracy and high yield. I believe verification is possible. In order to achieve such a capability, it will be necessary to test at full range and at as near operational conditions as possible. Such tests can be monitored to determine the number of reentry vehicles. No nation would replace existing reliable missiles and consider initiating a nuclear war with a missile which had only been partially tested. Planners would demand high confidence on the reliability and accuracy of the full system before risking national suicide by carrying out a first strike.

USEFUL TESTS

Tests in which only one of the multiple warheads was allowed to separate would be useful for development but not satisfactory for proving out the complete system. Such tests would in any case probably raise suspicions. Likewise, simulated tests in space or, as has been suggested in analogy to the proposal for evading the Nuclear Test Ban Treaty, "tests behind the moon" would be equally unsatisfactory. Elaborate schemes for clandestine testing will undoubtedly be put forward as they were in the case of nuclear weapons testing, but even with much simpler systems than MIRVs, military planners like to see full operational testing before undertaking deployment. For example, even more than five years after development testing has been completed on the Polaris A3 MRV system, the military are claiming that additional firings of the complete system are essential to maintain confidence in its operational capability. Based on past experience the Soviet military are even more stringent than the United States in their requirements for full operational testing. It is most unlikely that the Soviets could, without U.S. knowledge, violate a MIRV-MRV test ban to the extent that they would be in a position to deploy a MIRV system which would be sufficiently reliable and accurate to threaten to destroy the entire Minuteman force.

The Soviets have no known present program for deploying a new truly intercontinental bomber. If they were to undertake such a deployment in violation of a ban, it is almost certain that the force would be detected before it had reached a significant size. Bombers are not easy to conceal, and U.S. authorities have known with confidence and publicly reported the size of the Soviet bomber force since the mid-fifties. Suggestions have been made that they would masquerade such a force under the guise of supersonic transports which could be rapidly converted to bombers. Both Generals LeMay and Power have frequently emphasized that a bomber force which does not train and carry out realistic simulated operations is of almost no value. It is inconceivable that the Soviets could secretly create an operationally capable bomber force which could provide any serious additional threat to U.S. security.



ABM THREAT

Finally, going to strategic defensive systems, I shall concentrate on ABMs, since they pose the most serious potential threat to our confidence in our strategic deterrent forces and since they are the defensive system of most interest in any strategic arms limitation agreement. In 1966, Secretary MacNamara publicly announced that we had clear evidence that the Soviets were building an ABM system around Moscow, and the progress of this system has been reported on since at regular intervals. Secretary Laird has recently reported that a number of the complexes in this system were only brought to operational status this past year. Furthermore both Secretaries Clifford and Laird were even able to report that the deployment had been reduced in scope from that originally planned and that, on the other hand, the Soviets are continuing to press forward with R&D on a more advanced system. Secretary Laird also referred to large Soviet phased array radars for initial tracking and warning. I am confident—and these statements are a public substantiation—that we are now capable of verifying a freeze on the deployment of ABM systems and that any significant violation could be detected well in advance of their becoming operational.

ABMs to cope with the sophisticated type threat of which the United States is capable are complicated and large systems. They require large radars which have a high visibility, have a long lead time for construction and which, furthermore, must radiate energy continuously if they are to be of any value. In addition, an ABM system requires large numbers of high performance defensive missiles if it is not to be saturated. Extensive training exercises must be carried out to develop operational competence. All these factors greatly facilitate the verifica-

Copyrighted material

tion of a freeze on ABMs. If, however, the limitation did not ban a nationwide net of large radars similar to the U.S. PARs (perimeter acquisition radars) and MSRs (missile site radar) and keep the number of missiles to low levels, then verification would be much more difficult since additional defensive missiles could be secretly produced and then rapidly deployed. Once ABM radars with nationwide coverage are in place, it will be much harder to verify any ABM limitations. The existing vulnerable early warning radars (HENHOUSE) deployed on the periphery of the Soviet Union do not by themselves serve this purpose and would have to be backed up by other advanced radars nearer the ABM launchers.

A serious problem in the ABM area could be the confusion between systems designed for defense against aircraft with those designed for defense against ballistic missiles if the former were not controlled. For example, during the early construction period there was some doubt as to whether the Soviet's so-called Tallinn air defense system was for ABM purposes or not. However, as deployment proceeded, it became more and more clear that it was for defense against aircraft.

AIR DEFENSE

Nevertheless, fears still exist that the Tallinn or other air defense systems might be upgraded to provide an ABM capability without our knowledge. In evaluating this risk it is important to realize that any air defense system may have some limited capability to shoot down an incoming missile. However, to be a threat to a retaliatory attack of which the United States is capable and thereby erode the deterrent it must have an extremely high capability. Its radars must be able to handle rapidly large numbers of incoming targets and must also be defended. The missiles must have a high acceleration to avoid the necessity of committing the defense before the radar has determined the nature of the incoming objects. President Nixon has stated when the Safeguard decision was first made that the heaviest defense system considered, an ABM system designed to protect cities from a Soviet type threat, could not prevent a catastrophic level of U.S. fatalities. Clearly a Soviet system to cope with the even larger U.S. threat cannot be built by clandestinely upgrading existing air defense systems. New or large numbers of greatly improved radars, new missiles, new command and control systems and new radar defenses would be required if the Soviet antiaircraft systems were to be turned into even a partially effective ABM. Extensive troop training would be needed to develop operational effectiveness. Such a program would undoubtedly be detected with plenty of lead time to incorporate countermeasures to permit penetration of such a system. The U.S. already has developed and tested MIRVs capable of penetrating an ABM system, and these could be deployed in an emergency much more rapidly than a Soviet ABM.

BANNING ABMS

Thus it would appear that limitations on ABMs to low or zero levels can be adequately verified by national means. While some fears might arise about the upgrading of Soviet defense systems, it is believed that the risk to our security from such a secret program would be less than if there were no limitations on ABMs. It would be preferable to ban ABMs or restrict them to very low levels since, in these instances, radar deployments could be limited and thus facilitate verification.

Finally, I should like to point out that a broad freeze on offensive and defensive strategic weapons is easier to verify so as to maintain security than a ban on only one of the systems. For example, if ICBM launchers, MIRVs and ABMs were all frozen at their current status, a nation would have to succeed in violating, without being detected, in at least two of these areas before security could be jeopardized. In such a freeze a clandestine MIRV program for the SS-9 would not threaten the U.S. deterrent since the Soviets would be precluded from building more SS-9s or ABMs, and the U.S. would still have an assured destruction capability from the weapons which could not be destroyed by the Soviet MIRVs on its existing SS-9s. If only MIRVs were banned, then in time a clandestine MIRV program together with the permitted ABM and SS-9 deployments could be perceived as threatening the U.S. deterrent.

GEORGE H. QUESTER

Paris, Pretoria, Peking . . . Proliferation?

"The absence of French, South African and Communist Chinese signatures from the Nuclear Non-Proliferation Treaty does not immediately upset the Treaty. . . . We are prone to exaggerate the indifference of such nations to a further spread of nuclear weapons. Yet to demonstrate that fears are groundless does not terminate their political significance." George Quester is associate professor of government at Cornell University.

On a superficial first impression, there is a glaring weakness in the efforts of the United States and Soviet Union to stop the spread of nuclear weapons. The Nuclear Non-Proliferation Treaty limits possession of nuclear weapons to the five nations already in the "club," the U.S., USSR, U.K., France and China. Yet only three of these five nations intend to sign and ratify the treaty. These three will indeed refuse to give away nuclear weapons, and will assist peaceful nuclear projects only where IAEA safeguards ensure that no weapons are produced. But won't the Treaty be meaningless if France and China are free to offer bombs to anyone that asks for them? Supporters of NPT can respond that the gap will be filled if most potential recipients of nuclear weapons sign the Treaty, i.e., promise not to accept such gifts. Yet abstentions by nuclear weapons nations may still make a great difference.

Some "near-nuclear" nations are already capable of making bombs without any assistance. Most however can do it much more easily with material or technical help from the outside. Indeed, if one were prepared to give complete bombs away, any potential receiving nation thereby becomes a "near-nuclear" power. France and China can give bombs away if they want; they have not legally promised not to. They can also give away technical information on how to produce bombs. Some other states are similarly significant in that they can sell or give away uranium, the material of which bombs are made. What if they also refuse to sign NPT?

For the moment, the attitude of Paris seems reasonably clear. France, its foreign minister has said, will not sign NPT, but will behave just as a signatory would. We will, of course, never receive an exact accounting of the assistance France rendered to Israel, or a denial that France left any bombs with its one-time partner. Also left unsettled are the rumors that Israeli scientists contributed to French progress on the H-bomb. Presumably, any such cooperation has now been terminated by political developments other than NPT.

We can also not be certain that nonsignatory France will interpret NPT quite as strictly as will signatory states. France will not give away bombs; but would she sell India or someone else crucial components, enabling that country to escape IAEA safeguards and then to make it's own weapons? Even the signatories will argue about which sales are allowed and which are forbidden to a state rejecting safeguards. Whenever France and India negotiate any agreement on heavy water, etc., some part of the world public will again fear an undermining of NPT.

Bombs can be disseminated by nuclear-weapon nations and/or by nations controlling sources of uranium. In descending order, the three most significant sources of uranium are the United States, Canada and South Africa. As one of the nuclear-weapon nations that wrote NPT, the position of the United States is clear. Canada's position is also reasonably clear, a combination of moral objection to the spread of weapons and general aversion to the vagaries of the uranium market. Having suffered economically when the United States curtailed its own production of warheads abruptly in the early 1960s, Canada is not likely to become enthusiastic about potential uranium markets to be found in other countries. In any event, Canada has signed and ratified the Non-Proliferation Treaty.

SOUTH AFRICA

The Republic of South Africa may be more of a problem. South Africa has not indicated as yet any intention of signing NPT. As a semi-outcast in the international community, Pretoria has a difficult path to tread. There might be gains to bypassing the international system with uranium sales in special circumstances, but there will also be strong arguments for cooperating with the system, tacitly or explicitly.

Of those states which are imminently interested in nuclear weapons, there are a number which would seem to be disqualified from partnership with South Africa. India, Pakistan and the United Arab Republic all have explicitly denounced the white regime. In extremis, one of these states might quietly accept uranium even from the devil, but it is hard to see what South Africa could be offered in return. Cash payments might more easily ease South African qualms on sales to Germany, Japan, Brazil, Australia or Argentina, if these states remain outside the NPT system. As will be seen, however, cash considerations can also make South Africa support NPT and the IAEA.

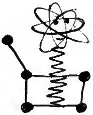
There has been speculation on cooperation between Israel and South Africa, some of it maliciously originating from Eastern European sources which like to lump together the regimes they oppose. Israeli involvement in Black Africa may superficially stand in the way of cooperation, as might the occasional anti-Semitism that emerges in South Africa, but both countries could indeed overlook this if grander projects were involved. One could obviously speculate on a deal whereby both states got nuclear weapons, combining South African uranium and Israeli expertise. Cooperation in the sharing of other military hardware might bring the two countries together also, as each is under a slightly different kind of arms embargo. Yet there will still be important arguments against South Africa so brazenly defying the world's consensus on proliferation.

ARGUMENTS

First, because of the revenue they earn in selling uranium to the legitimate peaceful power reactor market, South Africans will have to be concerned. This market now promises to expand rapidly in the 1970s; but the appearance of a sixth nuclear power could substantially hamper this, as the United States and other technologically advanced states become reluctant to license or sell reactors, or to process fuel. The Republic has thus several times stated that it will not allow its uranium sales to be used to increase the number of nuclear-weapons nations.

There is also something dignifying and stabilizing for South Africa in being a supplier of uranium, just as in being a source of gold. But for this, the style might be more parochial, xenophobic or radical. If NPT induces the world to tolerate a great expansion of nuclear power production, it would be short-sighted and foolish for South Africa to rock the boat. Of course, NPT might hurt the uranium market by fracturing it into signatory and nonsignatory blocs, with conflicting incompatible control systems. If it wins widespread acceptance, however, it can ease barriers to fuel transfers and sales, as the IAEA safeguards become standardized and replace bilateral or Euratom arrangements. The Republic's current reluctance to sign the Treaty thus might simply reflect an uncertainty on how the Treaty will be accepted elsewhere, that is, whether it will stabilize or upset peaceful nuclear development.

For the moment, most of South Africa's uranium sales depends on the enrichment services of some other nation. The market for uranium is essentially divided into two clusters: installed power reactors which require enriched uranium as a fuel, and reactors which can utilize natural uranium. Countries with natural fuel reactors can come to terms directly with the Republic, and could presumably produce plutonium for atomic bombs directly from South African uranium. A nation requiring enriched uranium, however, will have to find some means to preprocess the South African product. For the moment, there are few such enrichment facilities available outside the current nuclear-weapon nations, indeed outside the United States. The USSR, France and China have facilities for enriching uranium; Britain has a facility which was shut down for a time, but may now be reopened if the commercial demand for enriched uranium makes it profitable. Proposals for gas centrifuge processes are under study by an Anglo-Dutch-German consortium, and in Japan. If these nations sign the Treaty, however, their facilities and any materials passed through them will also be under IAEA safeguards, whether or not South Africa signs NPT.



Pretoria may thus be dissuaded from delivering uranium to the "sixth" nuclear-weapon nation. Yet one must also consider the Republic's option of itself becoming the sixth. Under present circumstances, South Africa stands to gain less than it would lose in making nuclear weapons itself. The conventional superiority over any political opponents in Africa is so clear that it would hardly seem advisable to change the rules of the game. The Republic generally seeks to avoid publicity, and a nuclear-weapons program surely would focus the world's attention all the more on South Africa. If some other state, for example India, breaks the ice by becoming the sixth nuclear power, the Republic could then more easily contemplate conspiring with someone to become the seventh and eighth. At the moment, a move toward nuclear weapons would rouse great opposition and emotion, in Africa and out.

COMPLICATIONS

Several kinds of circumstances might thus be required to make South Africa willing to dispense uranium without safeguards. If NPT fails to pull in most of the significant near-nuclear nations, e.g., if Germany and Japan and Italy try to go it alone in refusing to ratify, South Africa could be guided in this direction simply by economic considerations. Even without safeguards, such markets would be difficult to pass up. Alternatively, if political and military events lead the Republic to feel a need for nuclear weapons, or for some other special kind of weaponry, it might be ready to offer its uranium in exchange. Finally, there might be some other special favor which another nation might be able to grant in exchange for assistance on nuclear weapons. If the analysis above is correct, however, it would have to be an extremely big and necessary favor to make such a defiance of NPT worthwhile.

None of this necessarily requires

that the Republic sign NPT. South Africa can certainly observe the Treaty without signing it. As an important supplier rather than receiver of critical materials, it can afford to mold a policy of its own, demanding safeguards over most or all of its sales. There are some clear bargaining arguments for such a noncommittal position, whereby South Africa would cooperate with the NPT system, but not bind itself to do so forever. On a year-by-year basis, the threat of unsafeguarded uranium sales can be held in reserve to deter overly-stringent boycotts and embargoes, to force the United States and Britain to accommodate South African interests where such accommodation is crucial. In this light, it would be optimal for South Africa neither to surrender nor to exercise the option of spreading nuclear weapons.

Aside from this residual threat of selling uranium to weapons producers, the Republic might withhold an NPT signature simply to avoid unnecessary IAEA inspection of South Africa. Reactors purchased from abroad will, of course, have to come under IAEA safeguards on a project-by-project basis, but at least the uranium mines can escape inspection. At the moment, IAEA safeguards procedures do not extend to mining, but NPT fairly clearly calls for an extension of such inspection to mines as well as reactors. South African failure to sign the Treaty may thus reduce potentially troublesome access by outsiders to the Republic. It could maintain a secrecy on exact amounts of gold and uranium production; the two are somewhat conjoined. Such secrecy is certainly important for merchandizing gold; it might someday also facilitate the clandestine sale of uranium.

CHINA

Peking, a third possible threat to NPT, normally draws the most speculation and attention. Chinese communist statements in the past have suggested that it would be desirable if all socialist nations possessed nuclear weapons. Other pronouncements have declared that no nation can deny another nation the right to such weapons. Denunciations of the Non-Proliferation Treaty have been forthcoming ever since it became clear that the U.S. and USSR might agree on such a pact.

Given Chinese interests in various parts of the globe, it has thus been quite plausible that Peking might deliver weapons to nations requesting them. Leaving aside various national liberation movements, which are not likely recipients of nuclear weapons from anyone, two specific possibilities have drawn some comment—Pakistan and U.A.R. There are many similarities between the two. Each has a hostile neighbor known to be capable of early manufacture of atomic bombs. Each has despatched delegations of physicists to China; whatever the intention, this has encouraged speculation on nuclear weapons assistance from Peking.

At first glance, outsiders might wonder what will prevent such transfers from occurring. Pakistan will not sign NPT until India does, which probably means never. Egypt signed the Treaty under obvious Russian pressure, but will not ratify it unless Israel signs and ratifies. Peking is at least nominally committed to great sympathy for proliferation to such nations.

MORE PROBLEMS

If India definitely acquires nuclear weapons, Pakistan may very much want to do the same. In the worst of situations, nothing else might suffice to deter the use of Indian bombs. Long before this calamity, the psychological inferiority suggested by Pakistan's non-nuclear status might seem undesirable. As long as India has not yet manufactured any nuclear explosives, a Pakistani request for such weapons may seem less likely, for Rawalpindi clearly prefers a nonnuclear confrontation with its only adversary. Unfortunately, however, New Delhi senses two adversaries, one of which, China, has already gone nuclear.

If Israel definitely acquires nuclear weapons, the U.A.R. may very much want to do the same. There have been rumors that Egypt sought a promise from the USSR that it would be provided A-bombs if Israel manufactured its own, a request which the Soviets rejected. The wording of NPT in any event makes it illegal for the Russians to give nuclear weapons to the U.A.R., even if Israel has acquired its own. Again the U.A.R. might be expected to turn to Peking for the same declaration, since Peking will not be bound by the Treaty. Indeed, Egypt might want to acquire nuclear weapons from China even before Israel had acquired them, for its hopes for peace are hardly as high as those of Pakistan with India.

PEKING A FACTOR

Yet there are contrary considerations for both Pakistan and the U.A.R. which make any immediate transfer of nuclear weapons from China much less likely than the pessimistic picture would have it. The U.A.R. is heavily dependent on Russian military assistance; Pakistan is seeking to acquire such assistance. The Russians are opposed to proliferation and are at odds with China. For either Pakistan or Egypt to become so visibly involved with Peking might alienate much more immediately necessary assistance in the conventional weapons field—the atomic bomb is not a panacea which quickly replaces all this. Moreover, neither Pakistan or Egypt has totally burned its bridges with the United States, and would surely be doing so if either one were to announce an agreement for nuclear weapons from Peking.

The reactions of the United States and USSR might go beyond cut-offs in aid. The United States, for example, might try to blockade all Chinese shipments to Egypt if it had been made clear that nuclear weapons were being handed over. World public opinion could well be marshaled behind strong sanctions against any nation which thus brazenly attempted to become number six in the nuclear club. Much would depend, of course, on whether Israel or India had already reached for the bomb and public opinion had been mobilized against them.

If the Chinese were willing to give bombs away, Pakistan and Egypt might be reluctant to accept them. Yet there is also good reason to assume that Peking is not at all anxious to give them away. Since the first detonation of a Chinese bomb in

"PSST— MISSILE INSTALLATIONS.

1964, there have been some significant hedges on Chinese statements on nuclear proliferation. There are pronouncements that the assistance of one nation to another is entirely appropriate in regard to the peaceful uses of nuclear energy, but that it it best for a nation seeking weapons to develop them itself. (Perhaps thus a nation may retain its independence and self-respect?)

Within the last two years, there have been more specific statements accusing the Japanese government of aspiring to manufacture nuclear weapons, and declaring that Japan under no circumstances should consider doing so. The Pro-Peking Communist Party in India has similarly oposed any Indian move toward nuclear weapons.

A RELUCTANCE

Ever since detonating its first bomb, the Chinese Communist regime has declared its commitment to a "no-first-use" policy, whereby it would only use nuclear weapons if some other nation had done so first. No other nuclear-weapon nation has so clearly circumscribed the cases in which it would use its arsenal. The Chinese statements at times have suggested that nuclear weapons would not be used even if an American army were to invade China, as long as the Americans had not used them first. Releasing control over such weapons to other nations would appear to conflict with this apparent desire to keep all wars non-nuclear.

The statements to date thus do not firmly require Peking to refuse requests for nuclear weapons, but they certainly allow for such a refusal. The diplomatic reluctance of Cairo and Rawalpindi to become tied clearly to Peking will also make the Chinese reluctant to make firm offers of nuclear weapons aid. It would be humiliating, at the least, for Peking to be on record—publicly or even privately—with a firm offer as long as the recipients will not publicly commit themselves even to being interested. There is no evidence that private Pakistani and Egyptian talks with the Chinese have gotten down to cases on possible proliferation; there are indications that they have not, that the Chinese have not been inviting discussion of this possibility at all.

The argument has been stated persuasively that donations of nuclear weapons might fit in well with the general Chinese approach to world political unrest, a low-cost donation with a high return of political confusion. Yet the opposite case can be persuasive as well. China has not professed to attach great significance to its own bombs; as mentioned above, they are to be used only if others use them first. Peking still attaches primary significance in its propaganda to well-founded guerrilla movements. To pass bombs around reverses all this in the eyes of the world. In the Middle East, it diverts attention from Al Fatah toward the U.A.R.'s government in Cairo. In general, it invites comparison with the strategic weapons Moscow could have offered; in techniques of guerrilla warfare, Peking can claim a special advantage, but in bombs it can not.

If one releases five or ten atomic bombs into the hands of the Arab governments, the follow-up influence one has earned may not be extensive. A long and gradual guerrilla campaign with Chinese instructors and Chinese machine guns promises much greater leverage, as well as being more consistent with the "man over weapons" ideological theme from which Peking has not yet deviated.

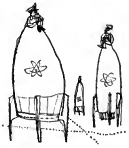
Despite American charges against China, moreover, Peking has not been adventurist. The guerrilla movements it has supported by and large seem to have a modicum of mass following and a chance of winning. To give nuclear weapons to small guerrilla movements would be adventurism, perhaps diverting them from the tried and true paths to victory, perhaps making no difference at all. To give nuclear weapons to regimes already established, regimes which might topple overnight—as in Ghana—would similarly be adventurism. A war in which nuclear weapons were used by one or two regimes over which Peking had lost its control can hardly be viewed with equanimity in China. If nuclear weapons are used anywhere, their use anywhere else will be more likely, and Peking has shown every sign of hoping to reduce this risk to herself.

If there is one bona fide satellite or ally of China in the world, it is Albania. But Peking has said nothing about the appropriateness of Albania getting its own nuclear weapons. Rumors were spread in 1968 that China intended to deploy its own MRBMs (medium range ballistic missiles) to Albania, presumably thereby to be able to reach targets in Russia outside the striking range from Sinkiang. Yet even these would presumably have been under Chinese control, thus not constituting "proliferation," and no confirmation for such rumors is at hand. If one feared a Yugoslav, Western or Moscow-oriented takeover of Albania, nuclear weapons might indeed be a valuable deterrent; Chinese border conflicts with the USSR similarly might justify development allowing missile strikes along different azimuths. Yet the extent of Chinese caution is shown by Peking's unwillingness to comment openly on or confirm any such deployments; unadvertised, such deployments would lack much of their deterrent effect. Peking after all described Khruschev's missile deployment to Cuba as "adventurism" (while labelling the withdrawal as "capitulationism").

REMAINING THREAT

The absence of French, South African and Communist Chinese signatures from the Nuclear Non-Proliferation Treaty does not immediately upset the Treaty. In our imaginations we are prone to exaggerate the indifference of such nations to a further spread of nuclear weapons. Yet to demonstrate that fears are groundless does not terminate their political significance.

As long as Peking does not definitively commit itself to resisting proliferation, it will still be possible for weapons to spread from this source. None of the barriers cited above are necessarily permanent. Changes of government can occur which might reduce the Soviet connection as a factor. This would not even require coups which moved toward the Left domestically. If the Egyptian army, for example, were to depose Nasser and then oust the Soviet advisers, it might turn either to Washington or to Peking for support, and could well receive it.



For the moment, the proliferation scenarios remain linked to other potential nuclear-weapon programs. Israel and India are close to the development of nuclear bombs themselves, and other decisions must adjust to this. For Peking and for a potential nuclear bomb recipient, several contingency strategies must thus be considered. Nuclear weapons could be supplied quietly before any rival weapons programs reach fruition, to facilitate some grand preemptive sneak attack. Alternatively, such weapons already in place could be announced directly after India or Israel announced theirs, thus to establish an immediate counter-deterrent. There are drawbacks to any such transfer prior to the explicit provocation; supplying weapons to a "seventh" will be diplomatically much easier than having supplied them to the sixth.

A second approach would be to announce mutual agreement that Chinese weapons will be transferred as soon as, and not before, India or Israel acquires them. Unless accompanied by a clandestine prior deployment, however, this risks an attempt by someone to interfere with or preempt the transfer. Everyone today assumes that Peking, Cairo and Rawalpindi will be more amenable to a transfer if India or Israel receive nuclear weapons. Proclaiming this in advance has the advantage of putting it down clearly as a commitment, but it also inspires talk of China having acquired satellites, or fears that nuclear bombs have already been transferred.

But the reasoning here does not stabilize at any primary level. Even if China had no intention of introducing nuclear weapons into the Middle East, it encourages such a development by the failure to commit itself to resisting proliferation. One linkage is as follows: Some Israelis will wish to avoid renouncing nuclear weapons and submitting to IAEA inspection; domestically they will note that such inspection can not ensure that Egypt has not quietly received such weapons from China, even if the USSR can be trusted. If the U.A.R. were to gain control over such weapons when Israel had none, the weapons could easily come into use, either because the Arabs expected to win a war thereby, or because revenge for past defeats was now possible even without victory, through bombs on Tel Aviv and Haifa. The Israeli government responds to this domestic sentiment by failing to submit to guarantees which could assure the Arabs that no bombs were being assembled in Dimona or elsewhere; the Egyptians then turn to China with a stronger argument for a U.A.R. bomb.

IMAGES CRUCIAL

In discussions of arms control, one must be careful to consider thoughts about physical realities, as well as the realities themselves. Even if the physical problem poses no real problems, fears around them can take on life of their own. It may thus only require a plausible name on either side to stimulate precautionary arguments that snowball both sides of a conflict toward nuclear weapons. China suffices on the left, South Africa or France a little more remotely on the right.

The disincentives to these sources upsetting the Treaty are serious, but will not certainly always remain so. Worse, we can not guarantee that the images thus aroused will not stampede some part of the world into making the proliferation threat real. It is worth trying to get Treaty signatures from France, China and South Africa. If we can not, our problem is not at all hopeless, but it is a little more difficult.

REPORTS: *Environmental Disaster— Acts of Nature and Man*

Statue of Christ at Cemetery Hill overlooking Yungay, Peru.

The Peru Earthquake: A Special Study

A huge avalanche of ice and rock debris, triggered on the north peak of Nevados Huascaran by the May 31, 1970 Peru earthquake, buried the towns of Yungay and Ranrahirca, and killed more than 20,000 inhabitants — about 40% of the total death toll, according to scientists of the U.S. Geological Survey, Department of the Interior.

Dr. George Ericksen, a USGS geologist, Washington, D.C., and Dr. George Plafker, of the Survey's Menlo Park, California, office, who made a special study of the earthquake-affected areas at the request of the Peruvian government, said that the destruction wrought by the avalanche "was almost unbelievable, possibly surpassing in magnitude such catastrophic events as the Mt. Pelee eruption of 1902 on the Island of Martinique, and the eruption of Vesuvius in the year 79 A.D. that buried the city of Pompeii."

Ericksen said that the major geologic result of earthquake shock was the debris avalanche that originated in an ice and rock fall from Huascaran, the highest peak in Peru. He added: "Destruction and death due to collapse of buildings in response to seismic shaking was even greater than that due to the debris avalanche. It is estimated that more than 30,000 people were killed as a result of collapse of buildings.

"The avalanche started with the sliding of a mass of glacial ice and rock about 3,000 feet wide and about a mile long that swept downslope about nine miles to the town of Yungay at an average velocity of well over 100 miles an hour.

"The ice picked up morainal material as it moved down the mountain slopes, and by the time the mass reached Yungay is estimated to have consisted of about 80 million cubic feet of water, mud and rocks.

'The ice was partly converted to water by heat and friction in the rapidly moving mass. A mud flow of such proportion, originating from an ice flow, indicates a geologic process never before recorded."

Some of the "postscripts" to the Peruvian earthquake by Ericksen and Plafker:

The epicenter of the May 31, 1970 Peru earthquake, according to the Coast and Geodetic Survey, was located at Lat. 9.2S, and Long. 78.8W, or at sea about 15½ miles west of the port city of Chimbote in the northwestern part of the Department of Ancash. The initial shock, with a Richter magnitude of about 7.7 occurred at 3:23 pm, Peruvian time. Investigations indicate a maximum intensity of shaking in the coastal area between Casma and Chimbote. Intensity of shaking was less in the Santa Valley in the region from Huaraz northward to Huallanca.

VAST LOSSES

The affected area includes about 25,000 square miles, mainly the Department of Ancash, with an estimated population before the earthquake of 1,400,000. In addition to more than 50,000 killed or missing, about 50,000 people were injured badly enough to require medical treatment. A total of 186,000 buildings were destroyed, or rendered uninhabitable, representing an estimated 80 per cent of the houses in the area.

The extensive destruction to cities, towns and villages largely was due to poor construction of buildings, chiefly adobe, which had little shear resistance to lateral forces imposed by earthquake shock. The degree of destruction, however, was affected in some areas by differential compaction of geologic foundation material, generally unconsolidated sediments and rock debris of varied origin. In some areas, the damage was aggravated by incipient slumping or sliding of foundation material down hillslopes, by differential compaction of surficial materials, or by lateral extension of liquified sediments toward free faces with attendant surficial extension fissuring.

There was no significant vertical tectonic warping (crustal movement or deformation) along the coast, nor were there observable seismic sea waves (tsunami or maremoto) of the type that have accompanied previous great coastal earthquakes in Peru. This suggests an absence of shallow dip-slip faulting on the sea floor.

The major catastrophic result of the earthquake shock was the debris avalanche that buried the towns of Yungay and Ranrahirca, and damaged or destroyed several other small settlements and farms in its path. As it moved down the Rio Santa, it caused extensive damage to road and railway routes, the diversion dam and access bridge to the important Huallanca hydroelectric plant near the north end of the Canon del Plato and power transmission and communication lines.

The cataclysmic avalanche of ice and rock that fell from the glacier-covered 21,860-foot high north peak of Nevados Huascaran was by far the most destructive and geologically fascinating aspect of the earthquake. As it picked up water downslope from its source, the mass gradually took on the characteristics of a debris flow. Within a few minutes after the tremors were felt, an enormous mass of rock, mud, ice and snow had sped nearly nine miles down the west flank of the mountain to the Rio Santa, which was temporarily impounded behind a debris dam. More than 20,000 inhabitants of this lush agricultural region were swept away or buried by the debris, and an area in excess of 9 square miles was devastated.

The greatest loss of life and property resulting from the huge avalanche of ice and rock was at Yungay, a community that had a population of about 19,000. The dwellings and all but a few thousand of its inhabitants were obliterated by a relatively small tongue of mud and rock several feet thick that swept over a ridge 300 to 600 feet high between Yungay and the main stream of the avalanche which followed the Rio Llanganuco valley to the south. Only the tops of a few palm trees in the central plaza and part of the cathedral protrude above the mud to mark the site of this formerly prosperous and picturesque city.

The main part of the debris avalanche, which was channelled along the Rio Llanganuco valley, buried most of Ranrahirca as well as parts of all of several smaller villages along the fertile valleys of the Rio Llanganuco and Rio Santa. An estimated 1,800 people were killed at Ranrahirca and an unknown, but probably large, number of additional casualties were sustained elsewhere in the extensive area covered by the debris lobe. Only eight years earlier, on January 10, 1962, the Ranrahirca area was devastated by an avalanche from the same part of the north peak of Nevados Huascaran as the recent one. The 1962 avalanche of ice and rock wiped out nine small towns, including Ranrahirca, and killed 4,000 people. Unlike the May 31, 1970 avalanche, however, the 1962 event was not triggered by a felt earthquake, and the debris did not have sufficient velocity or volume to flow over the ridge between Yungay and the Llanganuco valley.

DESCENT RAPID

According to eyewitness accounts, the debris avalanche on Huascaran was triggered during the earthquake. It moved downslope at high velocity with a deafening noise and everywhere was accompanied or preceded by a strong turbulent air blast. Accounts of survivors suggest that the debris avalanche travelled the nine-mile distance from its source to the vicinity of the cemetery at Yungay in 2 to 4 minutes. A velocity on the order of 248 miles an hour is indicated near the middle part of the course by the trajectories of thousands of boulders, many weighing more than three tons, which in some places were hurled more than 2,000 feet from east to west across the Llanganuco valley. This deadly rain of rocks along the side of the Rio Llanganuco killed and injured many people and was extremely destructive to buildings, livestock and vegetation. The unusually high velocity and large volume of the debris avalanche allowed it to override topographic irregularities including the 300 to 600 foot high ridge between the Llanganuco valley and Yungay. Its momentum at the Rio Santa, almost nine miles from the source, carried it across the river, and as much as 175 feet up the opposite bank where it partly destroyed a small village.

The avalanche's velocity was due primarily to the combination of steep slopes (as much as 70 degrees) in the source area, and to the great vertical relief (nearly 12,000 feet) along its nine-mile path to the Rio Santa. The vertical drop in the upper half of its course is close to 10,000 feet with an average slope of 23 degrees. Frictional resistance to sliding of the mass may have been significantly reduced by a mixture of snow and ice and locally, perhaps, by the entrained air beneath the debris. Air-cushioned flow near the source is suggested by the fact that the debris avalanche apparently moved across ridges of unconsolidated morainal material without disrupting them.

It is estimated that throughout the length of the Rio Santa valley above Huallanca, a distance of about 80 miles, 90 per cent of the buildings have been seriously damaged or destroyed. This damage is due largely to adobe construction, which offered little resistance to earthquake shock, to thousands or tens of thousands of small landslides and rock falls and to the debris avalanche and flow from Nevados Huascaran. The most severe damage was to two-and three-story adobe buildings with heavy tile roofs. In addition, some brick buildings and a few reinforced concrete buildings were destroyed or damaged. Brick buildings without a reinforced concrete framework offered only a little more resistance to earthquake shock than did adobe buildings, although they rarely were totally collapsed.

Most deaths in Huaraz were in the older section of the city where collapse of two- and three-story adobe building killed both occupants and people who fled into the narrow streets for safety. In striking contrast, most of the few buildings in Huaraz of brick with reinforced concrete frames, including one of four stories and one of five stories, were only slightly to moderately damaged.

Landslides of all types, ranging from several tens of feet to a few thousand feet in maximum length, occur throughout the steep slopes, both of the Cordillera Negra and Cordillera Blanca. Such landslides were triggered by the combination of lateral and vertical accelerations imparted to the slide masses during the seismic shaking. Most of the rock and soil falls are on steep, relatively dry slopes. Some larger rotational slides and surficial slumps, particularly those near the bottom of the Santa Valley and intermediate slopes of the Cordillera Blanca, are in water saturated ground where dynamic ground-water loading in the pores and joints of the affected materials probably increased the susceptibility to sliding. A record rainfall during the past wet season, which included unusually heavy rains as late as May 17, probably contributed significantly to the amount of landsliding.

Many faults exist in the Santa Valley, but apparently none moved during the May 31, 1970 earthquake. The most prominent recent faults of the area are along the foot of the Cordillera Blanca. They are marked by an en-echelon system of fault scarps as much as 20 feet high that cut Holocene (about 10,000 years old) glacial moraines. Although it is evident that these faults have moved recently (perhaps at some time during the past few hundred years), there is no evidence of movement during the May 30 earthquake.

Severe earthquake damage occurred in the coastal region of Peru from Trujillo on the north to the village of Las Zorras on the south, a distance of about 160 miles. Throughout this area, there has been major damage or total destruction of adobe buildings, which constitute a large proportion of residences. New brick houses lacking reinforced concrete pillars, which are found in some communities, and particularly in one entire subdivision if Chimbote, have been seriously damaged or destroyed. Well-constructed houses and buildings consisting of reinforced concrete pillars and connecting stringers with brick wall panels, generally show little or no damage, although they may be entirely surrounded by demolished adobe structures. The few wood frame buildings in the area likewise were essentially unaffected by the earthquake.

Because the earthquake occurred on a Sunday aftrnoon, when school was not in session and businesses were closed, the number of deaths in the coastal area was relatively low, probably about 1,000. About 700 coastal casualties were in Chimbote, and resulted from collapse of structures on their occupants or on people who fled into narrow streets. The total number is small considering the regional population of nearly 200,000, and the extent of destruction. By rare good fortune, Casma, which formerly had a population of several thousand, and which was almost totally destroyed, recorded only 70 deaths.

Fissuring, slumping and differential ground subsidence are extensive in swampy areas and areas of near-surface ground water table in the valleys and along low-lying coastal segments. In these areas, fissures several inches wide, subsidence of roadbeds and cracking and slumping of roadway embankments caused temporary disruption to transportation routes. Fissures also developed in cities and towns due to differential settlement along the junction of filled areas and natural deposits, and to lateral spreading of liquified saturated sand. At the port of Casma, and in near-shore areas of Chimbote, spreading due to liquifaction of delta and beach deposits produced numerous extension cracks in the ground that literally tore apare all the structures they intersected.

In some areas of near-surface ground-water table, seismic compaction of surface deposits lowered the land surface sufficiently to cause flooding. An extensive flooded area formed in this way extends over a large part of a residential area in southern Chimbote. Houses here were totally destroyed or nearly so, and water covers former house floors to depths of several inches.

Sand boils are numerous and large in some areas. These resulted from squirting of muddy and sandy water from fissures that opened during earthquake shaking in response to compaction and cracking of the water-saturated surface deposits. The sand boils are commonly marked by a central hole a few inches to about three feet in diameter, surrounded by a mound of ejected sand and silt up to 50 feet in diameter.

W. T. PECORA

Science and the Quality of Our Environment

The environmental crisis has provoked a gamut of opinion, from the alarmists who assert that mankind may not survive another decade to the stand-patters who denounce the crisis as a Leftist plot. Sober citizens, recognizing the complexity of the problems as well as the urgent need for constructive action, look to the experts—to the scientists and technologists—for guidance. There is hope for an adequate response, according to the author, because a new ethic is developing in American science, and scientists who years ago merely looked out of the windows of their ivory towers are now walking down the steps to join the world around them. W. T. Pecora is director of the U.S. Geological Survey. This article is adapted from a June 1970 commencement address presented by Dr. Pecora at George Washington University.

Primitive man took what he could from nature to stay alive, and he stood in awe of natural phenomena he could not understand. From this precarious beginning evolved a complex society which still takes from nature to fulfill its needs. In some quarters, man is now indicted for all his environmental ills; and yet in others, it is held that nature must be shaped as man requires it.

The ability to maintain an acceptable environment, however, can be hindered by failure to recognize fundamental earth processes. Environmental degradation is a natural procedure on earth, but man is beginning to contribute to that degradation in large measures in certain areas. Not all modification of our environment is degrading. Some alteration is acceptable. Hazardous changes must certainly be avoided. It is inexcusable that we should fail to predict responses of nature consequent to our own actions. Man has begun to develop an awareness that better housekeeping of the earth must be practiced as he continues to take from the earth the things he needs and uses.

MAN IS EARTHBOUND

For some five billion years the planet Earth has revolved about the sun; and there is good reason to believe its journey will extend beyond another five billion years. Throughout this period the earth has undergone constant change: mountains have risen where oceans formerly existed; animal and plant species have flourished and become extinct; earthquakes and volcanoes have always been with us; rivers and plains have appeared and reappeared; and glaciers have covered large segments of the planet many times. Although on Earth but a few million years at the most, man has in the past 200 years unraveled a great deal of earth history and learned how to use the planet to meet his growing needs for survival.

As earthbound residents, we look constantly, nevertheless, to other planets. The moon, satellite of the earth, has already been visited and found to be totally hostile to man. The surface of Venus is too hot for us, and Mars offers little, if any, hope. The other planets are out of the question. Man, indeed, is earthbound and we must learn to accept this inescapable circumstance however great our expectations.

Man has achieved phenomenal advance over 10,000 years in the face of a world population increase from a few million then to 3.5 billion today. The complex development of society over this period was accomplished because man has an intellect that can innovate, plan, acquire information, store it, pass it along to succeeding generations and increase the level of his systemic intellect through research and development.

Man now truly inhabits the entire planet. He has crossed mountains and oceans, explored the poles and burrowed deeply underground. The primitive observer of nature has developed into the creative scientist of modern society. Those quinqueremes of Nineveh have developed into sleek jet aircraft; simple mathematical devices that were developed separately in different civilizations have grown into complex modern computer systems; signal drums have blossomed into telecommunications systems that link hemispheres. Real time for man now has real meaning. Status quo may have meaning for other species on earth; but for man there is no status quo because of his intellectual capability.

BY THE YEAR 2000

Let's take a look at the mineral resource needs of the society that makes up the United States of America. Within the life span of 200 million people now living in the United States, this nation will consume from the earth:

6.5 quadrillion gallons of water
7.5 billion tons of iron ore
1.5 billion tons of aluminum ore
1 billion tons of phosphate rock
100 million tons of copper

In 40 years, our population will double. Just think of the added requirements of the next generation: By the year 2000, water usage will triple, energy requirements will triple, and we will have to construct as many more houses and other facilities as now exist in the United States.

This staggering amount of natural mineral resources upon which the sustenance of the nation depends imposes a tremendous task of new discovery and new development.

Cerro Negro Volcano (Nicaragua) blanketed the countryside and the city of Leon (17 miles distant) with ash from October 23 to December 7, 1968.

How can we do this without changing the character of our environment? For society must also provide against excessive noise, excessive pollution and excessive degradation of the landscape and of the waters.

If this be the situation for the United States, certainly resource needs for the rest of the world command even greater attention. Developing nations seek fulfillment in health and economic betterment. The crust of the earth which provides these resources is worldwide and knowledge about it gained in one country can be used to good advantage by scientists and engineers in others. Does the crust of the earth have the potential to provide for man's needs? The problem for mankind is universal — planetary — not national. Wars must cease and man's society must one day be planetized if the species, homo sapiens, shall persist on this earth.

Since we must take from the earth to provide for ourselves we must employ value judgment and trade-off concepts in deciding how much to take from our environment, where to take it and how to leave it in the taking and using. Take and use we must, or we cannot survive as a species on earth.

EARTH INVENTORY

If the earth is to provide the materials for the survival of man's society, then a prudent society must provide for an intimate understanding of the earth: inquiry into geologic processes that have operated (and operate today) over the span of earth history; continuing inventory of current and potential resources; and continuing effort to develop new techniques for information-gathering systems. Research is a costly investment; but it pays off handsomely in long-term benefits. Too often a society thinks only of "now." The cumulative benefit of early research endeavors, on hindsight, is a superb demonstration that today's long term is tomorrow's short term. Time, for man, is a long continuum.

The best example of this is the research mapping systems that have been developed in the past. These include base topographic maps, geologic maps, hydrologic maps, geophysical maps, geochemical maps and thematic, environmental, special subject maps. All of these are the products of intensive research effort. I am concerned that the pace of doing this kind of work has slowed down in recent years, and I predict that our society will suffer for it because decisions will be made without background information. Our program priorities will have to be reordered because of increasing needs and resource conflicts of a world society that has a divine right under God to utilize our planet's total natural resources and to better the lot of man on Earth.

ENVIRONMENT MYTHS

The United States, from its very inception, has been accused of placing too much emphasis upon the accumulation of wealth and too much effort in raising, through industry, its so-called standard of living. This view was first stated unequivocally in 1831 by Alexis de Tocqueville, a French nobleman who visited this country when it had 24 states and 13 million people. Similar views are being stated today, as we have grown to 50 states and 200 million people. The American democracy and its free enterprise system is a great and successful experiment, the first of its kind in the history of civilization. I, personally, see nothing wrong with dedication of individuals, or groups, toward amassment of wealth through honest industry. But in the process of achieving these goals our mature society unwittingly — or knowingly — has permitted deterioration of other values, not measurable in dollars or numbers, and which affect the quality of individual life in many ways. Has the growth of science and technology in discovery and utilization of our basic resources failed in some ways and in many places to retain or fortify man's natural environment, or was the failure a result of inadequate planning — or perhaps too much economics?

Many people in this country believe that it is man who is degrading and polluting his environment because of our modern industrial society. Some myths, however, need to be destroyed. Let me cite a few to demonstrate that natural processes are by far the principal agents in modifying our environment. This is not to excuse or put aside what man does, but rather to put man's actions in proper natural perspective. Those individuals who speak about restoring our inherited environment of pure air, pure rain, pure rivers, pure lakes and pure coastlines never had a course in geology.

It has been calculated that more than 100 million tons of fixed nitrogen in the form of ammonia and nitrates are annually transferred from the atmosphere to the surface of the Earth as part of a natural precipitation process. In the United States alone there falls upon the face of our land annually more than four million tons of table salt, 2.5 million tons of sodium sulphate, and 36 million tons of calcium compounds — all in rain water.

Particulate matter and natural gases dispersed from the volcanoes is a continuing phenomenon. From three eruptions alone — the Krakatau eruption in Java (1883), the Mount Katmai eruption in Alaska (1912) and the Hekla eruption in Iceland (1947) — more particulate matter in the form of dust and ash and more combined gases were ejected into the atmosphere than from all of mankind's activity. Add to known volcanic activity the normal action of winds, forest fires and evaporation from the sea, and we can readily conclude that man is an insignificant agent in the total picture, although he is becoming an important agent in an extremely local context.

We have long been led to believe that water issuing from natural springs is pure and benefical to health because of its purity. The springs issuing into the Arkansas and Red Rivers carry 17 tons of salt per minute. In the Lower Colorado River, salt springs carry 1,500 tons of salt per day. The Lemonade Springs in New Mexico carry 900 pounds of sulphuric acid per million pounds of water (900 ppm) which is ten times the acid concentration of most acid mine streams in the country. Hot Springs in Yellowstone Park is likewise many times more acidic than the typical acid stream in a coal mining district. The Azure Yampah spring in Colorado contains eight times the radium that the U.S. Public Health Service sets as a safe limit.

The lakes and ponds throughout geologic history have gone through a life cycle of birth, maturity, old age and disappearance. No lake is truly permanent. The Great Salt Lake is nearing its dying stages. Once 20,000 square miles in area (Lake Bonneville), it is now only 950 square miles. Many thousands of years ago it was essentially a fresh water lake, fed during the pluvial period of the Great Ice Age; now it is about 10 times as salty as sea water.

NOT DEAD YET

We frequently hear that Lake Erie is dead. This is pure rubbish. Lake Erie is the shallowest of the Great Lakes, was created 10,000 to 20,000 years ago and, barring another Ice Age, has several thousands of years yet to go before senility. The western part of the lake is an extremely shallow shelf and receives a large amount of natural organic material transported from the surrounding terrain. Here is where the algae growth has always been present. Lake Erie, according to J. E. Kinney, has produced about 50 per cent of the fish catch of the entire Great Lakes system consistently over the past 100 years. This is not a mark of a dead lake. Green Bay, of Lake Michigan (so named by the first settlers because of the green color of the algae prevalent in the Bay) is, like the western shallow part of Lake Erie, the source of a great amount of organic matter — and fish! The food supply for aquatic life is high in these environments. The oxygen supply, unfortunately, diminishes as algae growth increases, as this portion of the lake becomes more and more shallow and as organic material is swept into the water, whether from natural or human sources. Every lake or pond, whether natural or man-made, faces a similar life history. The same is true of shallow estuaries. This is the natural law.

The rivers of our nation are being called dirty because of the works of man. We must understand that rivers are the natural transport systems for sediment and humus (organic matter) washed downhill by the rains that fall upon the land.

It is estimated that the Mississippi River carries into the Gulf a load of more than two million tons of sediment per day. This is equivalent to a daily load of 40,000 freight cars. The Paria River in Arizona is probably the dirtiest river in the world. It carries 500 times as much sediment as the Mississippi River per unit volume of water. This is a continuing condition year after year. Chemicals are also transported by streams in phenomenal amounts. The Brazos River of Texas, for example, transports 25,000 tons of dissolved salt per day. Peace Creek in Florida carries twice the concentration of flouride that is harmful to teeth. Many rivers and streams throughout the nation have natural qualities that do not meet the public health standards for drinking water.

The ocean has been the natural waste sink for the large-scale, natural pollution process of the earth. The character of the ocean itself has changed slowly throughout geologic time, while it has continually supported abundant life of all varieties.

MAN: GEOLOGIC AGENT

Although natural Earth processes dwarf the actions of man in a total context, it must be quite evident that man can become a major geologic agent in a specific or local context. This inter-reaction of man with nature is without question a most important issue of future years. In a society that has reached maturity in the industrial sense, the issue of environmental alteration becomes more and more acute. It is within this framework that certain actions 100 or 200 years ago are now considered sinful. What are some solutions to our dilemma?

The philosophy of engineering project cost is being modified to allow for certain actions which in the past were not factored into our cost analyses. A mineral resource, for example, should not be developed unless it is rich enough to support proper restoration or re-utilization of the land. A major pipeline traversing Alaska some 800 miles should not be constructed without added safeguards to protect the natural environment. Offshore drilling for petroleum should not be endorsed without the added cost of providing maximum safeguards against pollution. Cities and industries should not use the water available from natural sources without factoring in the cost of returning the water to a usable state. The smokestacks of our refineries and energy plants must not use materials that put unwanted matter into our air. The science and technology which have made possible the great advance of mankind can surely pay attention to these matters and resolve them.

Paricutin Volcano (Mexico) spewed ash and lava bombs on a once cultivated cornfield.

Who will bear the cost, however? Who will make the policy decisions? We know that government agencies have been urged by the people to regulate these matters, but who will pay the cost, for what I am convinced science and technology can do to ameliorate the situation? It must be the people. The people must pay the cost both in dollars and in acceptable landscape changes for taking from the environment what mankind needs, whether through tax participation or in the higher cost of a product. We who represent science and technology should be able to show how resources can be utilized with minimal alteration or degradation of the environment. We can do this, however, only by making a complete inventory of cause and effect, in other words, spelling out our costs and trade-offs in more than just dollars.

We find ourselves in the midst of a conflict between the need to develop the earth's resources and the desire to preserve the earth's environment — both, presumably, for the salvation of mankind. Industrial development has become synonymous with Wall Street, and American industry, envied around the world, is in trouble within its own country because of past abuses to the environment in the name of lowest cost. Profit has become an ugly word and the concept of science and engineering, once honored as a service to mankind, is now being widely ridiculed.

Must we choose between the two concepts, or can we seek balance as we move into the future? The first judgment must distinguish between danger and aesthetics, because change is inevitable in any developing society. The pace of change is a function of the choice of people, as it should be, if the people will speak out. Let us think about the words of Lowell in his tribute to Cromwell:

> New times demand new measures
> and new men;
> The World advances, and in time
> outgrows
> The laws that in our fathers' day
> were best;
> And doubtless, after us some better
> scheme
> Will be shaped out by wiser men
> than we,
> Made wiser by the steady growth
> of truth.

THE WILLIAMSTOWN STUDY OF CRITICAL ENVIRONMENTAL PROBLEMS

During July 1970, about 100 scientists and professionals conducted a month-long Study of Critical Environmental Problems (SCEP) on the campus of Williams College, Williamstown, Mass. The project was sponsored by the Massachusetts Institute of Technology and supported by nine federal agencies and six private institutions and foundations.

The focus of this effort was trained on environmental problems of worldwide significance. The Study was concerned mainly with the consequences of pollution in terms of changes in climate, ocean ecology and large, terrestrial, eco-systems.

In general, local and regional environmental problems, such as the thermal pollution of lakes and waterways, and the direct health effects of pollution on man were not considered. Nor did the Study examine in any detail the problems of radioactive waste disposal and the effects of nuclear power and Plowshare activities.

The pollutants it considered were those arising chiefly from the chemical processes and waste disposal practices of civilization. These included carbon dioxide (CO_2), sulfur dioxide (SO_2), oxides of nitrogen (NO_x), chlorinated hydrocarbons, other hydrocarbons, heavy metals and oil. Within this range, the Study produced an authoritative and thoughtful report. It may well become a launching platform for national and international programs of pollution control.

One of the striking aspects of SCEP is its humility. It does not attempt to ring the doomsday bell. Rather, it stands as a sober, reflective and careful statement of what man knows about the effects of these pollutants on the environment and what he has yet to learn. It thus becomes an assessment of the state of knowledge about these problems in the year 1970.

But SCEP does not quite stop there. It goes on to suggest what man can do about the problems he does understand and how he can acquire essential information about those he doesn't.

The Williamstown Study was made by as distinguished an assembly of scientists and professionals in law and social studies as ever addressed itself to the global pollution problem. There were experts in meteorology, atmospheric chemistry, oceanography, biology, ecology, geology, physics, engineering, economics and other social sciences. They were drawn from 17 universities, 13 federal departments and agencies, three national laboratories and 11 nonprofit and industrial corporations. About 40 worked the entire month of July on the study and 30 participated part-time. In addition, another 30 experts served as consultants.

The Bulletin *herewith presents the summary of the Study as presented at the conclusion of the Study July 31, 1970. The full text of this historic work is to be published October 15 by the Massachusetts Institute of Technology Press. (R.S.L.)*

Summary of Major Findings and Recommendations

THE PROBLEMS STUDIED

The global environmental problems studied by SCEP were:

Climatic effects of increasing carbon dioxide content of the atmosphere.

Climatic effects of the particle load of the atmosphere.

Climatic effects of contamination of the troposphere and stratosphere by sub-sonic and supersonic transport aircraft.

Ecological effects of DDT and other toxic persistent pesticides.

Ecological effects of mercury and other toxic heavy metals.

Ecological effects of petroleum oil in the oceans.

Ecological effects of nutrients in estuaries, lakes and rivers.

For these topics, the following general questions were addressed:

- What can we now authoritatively say on the subject?
- What are the gaps in knowledge which limit our confidence in the assessments we can now make?
- What must be done to improve the data and our understanding of its significance so that better assessments may be made in the future?
- What programs of focused research, monitoring and/or action are needed?
- What are the characteristics of the national and/or international action needed to implement the recommendations of the Study?

RECOMMENDATIONS

Carbon Dioxide in the Atmosphere

FINDINGS

All combustion of fossil fuels produces CO_2. It has been steadily increasing in the atmosphere at 0.2 per cent per year. Half of the amount man puts into the atmosphere stays and produces this rise in concentration. The other half goes into the biosphere and the oceans, but we don't know the partition in uptake, as between these two reservoirs.

The amount of CO_2 from fossil fuels is a small part of the natural CO_2 which is constantly being exchanged between the atmosphere/oceans and the atmosphere/forests. We have very little knowledge of such amounts.

The projected 18 per cent increase resulting from fossil fuel combustion to the year 2000 might increase the surface temperature of the earth .5°C; a doubling of the CO_2 might increase mean annual surface temperatures 2°C. Surface temperature changes of 2°C could lead to long-term warming of the planet. These estimates are based on a relatively primitive computer model with no consideration of important motions in the atmosphere, and hence are very uncertain but they are the best we have.

If we had to stop producing CO_2, no coal, oil or gas could be burned, and all modern societies would come to a halt. The only possible alternative is nuclear energy, whose by-products may cause serious environmental effects. Also, we don't have electric motor vehicles to be propelled by electricity from nuclear energy.

SCEP believes that the liklihood of direct climate change in this century resulting from CO_2 is small, but its long term potential consequences are so large that much more must be learned about future trends of climate change if society is to have time to adjust to changes which may be necessary.

RECOMMENDATIONS

1. Improvement of our estimates of future combustion of fossil fuels and the resulting emissions.
2. Study of changes in the mass of living matter and decaying products.
3. Continuous measurement and study of the carbon dioxide content of the atmosphere in a few areas remote from known sources — specifically four stations and some aircraft flights. We particularly recommend that the existing record at Mauna Loa Observatory be continued indefinitely.
4. Systematic study of the partition of carbon dioxide between the atmosphere and the oceans and biomass.
5. Development of comprehensive global computer models which include atmospheric motions and ocean-atmosphere interaction to study: circulation, clouds, precipitation and temperature patterns for expected CO_2 levels; and effects of stratospheric cooling.

Fine Particles in the Atmosphere

FINDINGS

Fine particles change the heat balance of the earth because they both reflect and absorb radiation from the sun and the earth. Large amounts of such particles enter the troposphere (the zone up to 40,000 feet) from natural sources such as sea spray, wind blown dust, volcanoes and from the conversion of naturally occuring gases — SO_2, NO_x and hydrocarbons — into particles.

Man puts large quantities of sulfates, nitrates and hydrocarbons into the atmosphere which become fine particles and include special species, such as urban smog.

Particle levels have been increasing as observed at stations in Europe, North America and the North Atlantic, but not over the Central Pacific.

We do not know enough about the optical properties (reflection versus absorption) of particles to know whether they produce warming or cooling of the earth surface.

RECOMMENDATIONS

1. Studies to determine optical properties of fine particles, their sources, transport, and amounts in both troposphere and stratosphere, and their effects on cloud reflectivity.
2. Extending and improving solar radiation measurements.
3. Study of feasibility of satellite measurements of particle concentration and distribution.
4. Monitoring from ground and aircraft — 10 fixed long-term stations and 100 stations for short-lived particles.
5. Develop atmospheric computer models which include particles.

Thermal Pollution

Although by the year 2000 we expect global thermal power output to be six times the present level, we do not expect it to affect global climate. Over cities it does already create "heat islands" and as these grow larger, they may have regional climatic effects and they should be studied.

Atmospheric Oxygen: Non-Problem

Atmospheric oxygen is practically constant. It varies neither over time (since 1910) nor regionally and is always very close to 20.946 per cent. Calculations show that depletion of oxygen by burning all the recoverable fossil fuels in the world would reduce it only to 20.800 per cent. It should probably be measured every 10 years to make sure that it is remaining constant.

Effects of Present Jet Aircraft

Observers all over the world have watched a jet contrail spread out to form a cirrus cloud. Observations at Denver and Salt Lake City show a systematic increase in such clouds since the advent of jets. Although they seem to be only regional, there is a possibility that they may have broader effects and should be studied.

SST's in the Stratosphere

FINDINGS

The stratosphere where supersonic jet transports will fly at 65,000 feet is a very rarified region with little vertical mixing. Gases and particles produced by jet exhaust may remain for one to three years before disappearing.

Using FAA estimates of 500 SST's operating in 1985-90 mostly in the Northern Hemisphere, flying seven hours a day, at 65,000 feet, propelled by 1,700 engines like the General Electric-4 being developed for the Boeing 2707-300, we have estimated the steady state amounts of combustion products using GE calculations of the amount of such products because no test measurements exist. We have compared such amounts of a steady state basis with the natural levels of water vapor, sulfates, nitrates, hydrocarbon and soot. All are believed to form fine particles. We have also compared these levels with the amounts of particles put into the atmosphere by the volcano eruption of Mt. Agung in Bali in 1963.

In our calculations we used jet fuel of 0.05 per cent sulfur. We are told that a specification of 0.01 per cent sulfur could be met in the future at higher cost.

We do not believe that CO_2 resulting from such operations is likely to affect the climate. We are genuinely concerned about the possibility of increased stratospheric cloudiness, and about the fine particles, even using the calculated amounts given us by GE.

Clouds are known to form in the winter polar stratosphere. Two factors will increase the future likelihood of greater cloudiness in the stratosphere due to moisture added by the SST. First is the increased stratospheric cooling due to the increasing CO_2 content of the atmosphere. Second is the closer approach to saturation indicated by the observed increase of stratospheric moisture.

The largest engine whose combustion products have been actually measured in static ground tests was the Pratt and Whitney-JT9D used on the Boeing 747. It's fuel consumption rate is one-third that of the GE-4. Combustion products from such tests of the JT9D, leading to particles, were much greater than the calculated values for the GE-4.

It is claimed that the particle formation is very small at 65,000 feet. Very, very little is known about reactions under such conditions. One guess is now as good as another.

Depending upon the actual particle formation, the effects of 500 SST's could range from a small, widespread continuous "Agung" effect to one as big as "Agung."

The temperature of the equatorial stratosphere (a belt around the globe) increased 6 to 7°C and remained at 2 to 3°C above its pre-Agung level for several years. No apparent temperature change was found in the lower troposphere.

Clearly such consequences are on a global scale even though the most pronounced effects would be felt where the highest density of traffic existed, i.e., the North Atlantic Ocean.

CONCLUSIONS

SCEP concludes with respect to contamination of the stratosphere by products of SST's that:

1. CO_2 creates no problem.
2. Global water vapor may increase 10 per cent; increases in regions of dense traffic may go

The U.S. supersonic transport, Boeing designed.

up 60 per cent.

3. Particles from SO_2, hydrocarbons and soot may double pre-Agung global averages and peak at ten times those levels where there is dense traffic.
4. Effects of climate could be increased clouds from water vapor, and increased temperatures in the stratosphere with possible increase in surface temperatures.
5. A feeling of genuine concern has emerged from the above set of conclusions. The projected SST's can have a clearly measurable effect in a large region of the world and quite possibly on a global scale. We must emphasize that we cannot be certain about the magnitude of the various consequences.

RECOMMENDATIONS

1. That uncertainties about SST contamination and its effects be resolved before large scale operation of SST's begins.

2. That the following program of action be commenced as soon as possible:

a. Begin to monitor the lower stratosphere for water vapor and particles and develop means to measure SO_2, NO_x and hydrocarbons.

b. Determine whether additional cloudiness will occur in the stratosphere and the effects of such changes.

c. Obtain better estimates of emission of combustion products under simulated flight conditions and under real flight conditions at the earliest opportunity.

d. Using data resulting from a, b and c, estimate effects on weather and climate.

DDT and Related Persistent Toxic Pesticides

The ecological effects which have been identified with DDT are both general and specific. In general, the use of pesticides on crops generally requires continued and increased use of different and stronger pesticides. This is the result of a complex ecological system in which the reduction of one pest and innocuous (to man) predators allows new pests to become dominant. As one example, the egg shells of many birds are becoming thinner reducing hatching success. In several species, these effects now seriously threaten reproductive capabilities. Damage to these predators in the ecological system tends to create a situation in which pest outbreaks are likely to occur.

The concentrations and effects of DDT in the open oceans are not known. There are no reliable estimates and no direct measurements have been made. It is known that large amounts leave the area of application through the atmosphere and are transmitted through the world and some portion of this falls into the oceans.

DDT collects in marine organisms. Detrimental effects have not been observed in the open ocean, but DDT residues in mackerel caught off of California have already exceeded permissible tolerance levels for human consumption. It is known that reproduction of fresh-water game fish are being threatened. The effect of DDT on the ability of ocean phytoplankton to convert carbon dioxide into oxygen is not considered significant. The concentration necessary to induce significant inhibition exceeds expected concentrations in the open ocean by ten times its solubility (1 ppb) in water.

As DDT is being phased out, control measures must be accomplished through a variety of existing techniques such as biological controls and environmental management in addition to the use of degradable insecticides to offset food and health problems in the developing countries.

RECOMMENDATIONS

1. We recommend a drastic reduction in the use of DDT as soon as possible *and* that subsidies be furnished to developing countries to enable them to afford to use nonpersistent, but more expensive, pesticides and other pest control techniques.

2. In order to obtain information about the concentrations and effects of DDT in the marine environment, a baseline program of measurement should be initiated. This might involve taking about 1,000 samples at selected locations and analyzing them over the course of a year. A full-scale monitoring program should await the results of such a program.

3. We recommend greatly increased effort and support for the research and development of integrated pest control, combining a minimal use of

pesticides with maximal use of biological control.

Mercury and other Toxic Heavy Metals

FINDINGS

Many heavy metals are highly toxic to specific life stages of a variety of organisms, especially shellfish. Most are concentrated in terrestrial and marine organisms by factors ranging from a few hundred to several hundred thousand times the concentrations in the surrounding environment.

The major sources of mercury are industrial processes and biocides. Although the use of mercury in biocides is relatively small, it is a direct input into the environment. There are many other possible routes but little data exists about the rates of release to the environment.

RECOMMENDATIONS

1. Pesticidal and biocidal uses of mercury should continue to be drastically curtailed, particularly where safer less persistent substitutes can be used.
2. Industrial wastes and emissions of mercury should be controlled and recovered to the greatest extent possible, using available control and recovery methods.
3. World production, uses and waste products should be carefully monitored.

Oil in the Ocean

FINDINGS

It is likely that up to 1.5 million tons of oil are introduced into the oceans every year through ocean shipping, offshore drilling and accidents. In addition, as much as two to three times this amount could eventually be introduced into waterways and eventually the oceans as a result of emission and wasteful practices on land.

Very little is known about the effects of oil in the oceans on marine life. Present results are conflicting. The effects of one oil spill which have been carefully observed indicate severe damage to marine organisms. Observations of other spills have not shown such a marked degree of damage. Different kinds of damage have been observed for different spills.

Potential effects include direct kill of organisms through coating, asphyxiation, or contact poisoning; direct kill through exposure to the water soluble toxic components of oil; destruction of the food sources of organisms; and incorporation of sublethal amounts of oil and oil products into organisms, resulting in reduced resistance to infection and other stresses or in reproductive successes.

RECOMMENDATIONS

1. Much more extensive research is required to determine the effect of oil in the ocean. Future oil spills should be systematically studied beginning immediately after they occur so that a comprehensive analysis of the effects can be developed over time. Sites of previous spills should be reexamined to study the effects in sediments.
2. Political and legal possibilities should be explored which would accomplish the conversion to Load-On-Top techniques by that 20 per cent of the world's tankers which do not use this method.
3. The possibility of recycling used oil should be explored.

Nutrients

FINDINGS

Eutrophication of waters through over-fertilization (principally with nitrogen and phosphorus) produces an excess of organic matter which decomposes, removes oxygen and kills the fish. Estuaries are increasingly being eutrophied. Pollution of in-shore regions eliminates the nursery grounds of fish including many commercial species which inhabit the oceans.

Most (probably between 60 per cent and 70 per cent) of the phosphorus causing over-enrichment of water bodies comes from municipal wastes. In the United States about 75 per cent of the total phosphorus in these waters comes from detergents. Urban and rural land runoff contributes the remainder (approximately 30 per cent to 40 per cent). A major contributor is runoff from feedlots, manured lands and eroding soil.

Trends in both nutrient use and loss are rising. Fertilizer consumption is expected to increase greatly in both developed and developing countries in the next decade increasing the nutrient runoff from agricultural lands. Concentration of animal production will continue with the result that losses of nutrients from feedlot runoff will quadruple by 2000. Urban waste production is expected to quadruple by 2000, which means greater potential loss of nutrients directly into coastal waters.

RECOMMENDATIONS

1. Develop technology and encourage its application to reclaim and recycle nutrients in areas of high concentrations, such as sewage treatment plants and feedlots.
2. Avoid use of nutrients in products which are discharged in large quantities into air or water. For example, reformulate detergents to eliminate or reduce waste phosphates, but be certain the substitutes degrade and do not poison the ecosystem.
3. Effect control of nutrient discharges in natural regions, such as river basins, estuaries and coastal oceans, through appropriate institutions.

Wastes from Nuclear Energy

It has taken our full efforts to probe in some depth a few questions. We decided deliberately to omit consideration of others of great importance. One of these is the problem of perpetual management of the large quantities of radioactive wastes which are by-products of nuclear power.

No other environmental pollutant has been so carefully monitored and contained. Yet, as we look back on our intense examination of the effects of the products of fossil fuel combustion, we have become aware of our neglect of a different class of pollutants which will grow greatly in quantity in the next 30 years.

We call to the attention of one of the sponsors of SCEP, the AEC, our decision to omit this item from our agenda and our concern about the subject.

RECOMMENDATIONS

That an independent, intensive, multi-disciplinary study be made of the trade-offs in national energy policy between fossil fuel and nuclear sources, with a special focus on problems of safe management of the radioactive by-products of nuclear energy leading to recommendations concerning the content and scale and urgency of needed programs.

GENERAL CONCLUSIONS

In studying the specific problems outlined above, SCEP reaffirmed the conclusions and principles which underlie the ecological, social and political implications of most critical environmental problems. Efforts to examine or ameliorate the effects of these problems should include explicit recognition of the considerations.

Ecological Considerations

An estimate is needed of the ecological demand, a summation of all of man's demands upon the environment, such as the extraction of resources and the return of waste. Such demand-producing activities as agriculture, mining and industry have global annual rates of increase of 3 per cent, 5 per cent and 7 per cent, respectively. An integrated rate of increase is estimated to lie between 5 per cent and 6 per cent per year, in comparison with a population rate of annual increase of only 2 per cent.

Natural ecosystems still provide us many free services. At least 99 per cent of the potential pests of man are held to very low densities by natural control. Insects pollinate most of the vegetables, fruits, berries and flowers, whether they be wild or cultivated. Commercial fish are produced almost entirely in natural ecosystems. Vegetation reduces floods, prevents erosion and air conditions the landscape. Fungi and minute soil animals work jointly on plant debris and weathered rocks to produce soil. Natural ecosystems cycle matter through green plants, animals and decomposers, eliminating wastes. Organisms regulate the amount of nitrates, ammonia and methane in the environment. On a geological time scale, life regulates the amount of carbon dioxide and oxygen in the atmosphere.

The functions of ecological systems connect the impact of man upon the environment with the services supplied by nature. Ecological impairment eventually leads to a loss of such services. The health and vigor of ecological systems are easily reduced if (1) general and widespread damage occurs to the predators, (2) substantial numbers of species are lost, or (3) general biological activity is depressed. Most pollutants that affect life have some effect on all three processes.

To prevent further deterioration of the biosphere, and to repair some of the present damage, action is urgently needed. In addition to a variety of specific recommendations such as those accompanying the specific problem areas, SCEP recommends that the following activities be developed in national and international programs:

a. *Technology Assessment:* An information center that centralizes data on products of industry and agriculture, especially new products and new increases in production. Such a center will also identify potentially hazardous materials, and promote research on their toxicity and persistence in nature.

b. *Environmental Assessment:* An information center that centralizes data on the distributions of pollutants, and on the health and pollution loads of organisms.

c. *Problem Evaluation:* A think-center to evaluate problems on the basis of the above information, to determine the urgency for action and to identify options.

d. *Public Education:* A service center to present the results of the above in simple form, and to distribute such materials to educational institutions and the news media.

Social and Political Changes

SCEP has concentrated on a few global problems. The main thrust of our recommendations is to gather more information about pollution of the planet. This information would improve our understanding of the impact of man's activities on the earth's resources of air, water and those on land: that is, the ecological demand of man's activities. Relevant data on critical global problems is very poor and this seriously limits our understanding of their meaning.

We have tried to estimate scales of world activities to the year 2000. In very few areas is there reliable data for projections. Indeed, much data about world activities today in areas of importance to this Study have been found fragmentary and contradictory. Far better estimates well into the 21st Century are needed in order to assess the expected impact of man on the world ecological system to give us time to take action to avoid crisis or catastrophe.

We have looked beyond the gathering of data and its interpretation to the question of how remedial action may be taken. Unless information leads to action to abate or control pollution it is largely useless.

Earlier in our history, the prevailing value system assigned an overriding priority to the first order effects of applied science and technology: the goods and services produced. We took the side effects — pollution — in stride. A shift in values appears to be under way that assigns a much higher priority than before to the control of the side effects. This does not necessarily impart a reduced interest in production and consumption. When the crunch comes — when the implications of remedial action and the choices that must be made become clear — will we have second thoughts? Or will we bog down in confusion and frustration? Will we hold to our course, insisting that our society make a more thorough and imaginative use of its resources of science and technology, its organizational skills and its financial resources in an effort to achieve an optimal balance between the production we need and the side effects which we must bring under control? We hope the answer to these questions is in the affirmative.

The problem of action is compounded because contributions to global pollution come from activities in countries all over the world. Action to control depends upon agreed data on amounts of pollution and their harmful effects. Actual control will depend upon national action by governments. It is not enough that the United States exercise control. If others pollute our common resources of the air and oceans, the perils remain. This challenge will be before the U. N. Conference on Man and the Environment in Stockholm in 1972. We hope that the SCEP reports will form useful inputs to that Conference, and that the SCEP study model may be applied to other critical problems of the environment.

TRENDS

TEKTITE III, ANYONE?

The Tektite II program in the Virgin Islands has been underway since April 1970 and is providing marine scientists with a unique and comfortable five-man ocean floor home/research laboratory. Teams of diving-scientists will continue to use this habitat on a rotation basis to further their in-situ marine research project until November 1970, at which time the present Department of the Interior program will expire.

Unlike other "low budget" habitat programs, Tektite offers the marine scientist underwater living comfort, extensive laboratory/work space in the habitat, excellent communications and short support facilities and a history of safe, reliable operation.

These factors make Tektite attractive to the serious scientist whose primary focus is his research investigation rather than on the distractions and annoyance of equipment problems and personal physical discomfort. Enthusiastic reports from scientists who have already used the Tektite habitat bear this out.

The Virgin Islands government is now planning a continuation program of marine science for the Tektite facility to begin in May 1971. Scientists are invited to submit outlines of research proposals, including personnel, equipment requirements and timing to the address listed below:

Ian Koblick
Special Assistant for Undersea Programs
P.O. Box 599
Charlotte Amalie, St. Thomas
U.S. Virgin Islands 00801

INDIA

The Central Pennsylvania Consortium consisting of Dickinson, Franklin and Marshall, Gettysburg and Wilson Colleges sponsored an eight-week India Institute June 29 to Sept. 1, 1970 at University of Patna, India.

Joint Indo-American ventures were doing well in 1969. Pfizer in India reported a 31.5 per cent gross return on total capital funds; Kirloskar-Cummins, Ltd. a joint venture with the Cummins Engine Co., Inc. (Indiana) reported nearly 100 per cent rise in profits before taxes and 48 per cent increase in sales. Madra Rubber Factory, Ltd., a joint venture of Mansfield Tire & Rubber Co. (Ohio) increased sales by 20 per cent.

UNIVERSITY RESEARCH

A Special Analysis of the President's 1971 fiscal year budget by NSF shows that federal support of research and development at universities and colleges decreased by 2 per cent between the 1968 and 1969 fiscal years. It increased by 2 per cent between 1969 and 1970. The budget asks an increase of 2 per cent in 1971 from fiscal 1970.

Between the 1958-66 academic years, expenditures on R&D by institutions of higher education grew at an annual rate of 17 per cent. The annual rate of growth was 11.6 per cent from 1966-68. During this period, federal funds financed 61 per cent of total university and college R&D expenditures, according to the NSF survey.

ANTI-POLLUTION

A Lake Charles, La., concern, CESO, Inc. has announced marketing of 110 detergent cleaning compounds which self-destruct to avoid pollution. The firm is selling 20 other compounds it claims reduce detrimental effect of phosphates in effluents and a series of emulsion cleaners that change into harmless wastes after use.

VINCENT J. SCHAEFER

Auto Exhaust, Pollution and Weather Patterns

"What I anticipate . . . is that the frequency of such unusual weather phenomena may increase as air pollution increases." Vincent J. Schaefer, a pioneer in cloud-seeding experiments, is director of the Atmospheric Sciences Research Center of the State University of New York at Albany. This article was adapted from his testimony in March 1970 before the Congressional Joint Legislative Committee on the Environment, Subcommittee on Air and Water Pollution.

I have been measuring atmospheric particles for more than 25 years. Much of the effort of my group at the University is directed toward basic and applied research in the air pollution problem.

I would like to present some of the evidence I have been accumulating for the past 10 years related to the effect on the atmosphere which is exerted by very small particulate matter and gases.

The particles I wish to discuss have a size range from 0.005 to 1 micron (μ) — the majority of them are smaller than 0.5μ and in fact many are quite invisible to the unaided eye. Even the most sensitive light microscope will not resolve most of them. While these particles have very little mass, they constitute the largest number of the particulates in polluted air. Concentrations of these particles in different environments are presented in the table.

The invisible effluent from the exhaust pipe of a typical automobile is a good example of the air pollution which concerns me. If one looks at the air along a freeway or other heavily traveled road, very little if any exhaust smoke can be seen coming from the traffic. Going through a long vehicular tunnel, however, a bluish haze will be seen in the air and if windows are open a foul smell can be noted. Such air contains tremendous numbers of small particles as well as gases of combustion, particularly CO, CO_2, the nitrogen oxides and hydrocarbons.

Measurement of the small particles in such restricted places will show values which may be higher than 500,000 particles per cubic centimeter (cc). Similar measurements along roads frequented by automobiles commonly exceed 150,000 per cc since the auto is now a major source of the polluted air in all large cities. Small particles, even those which are quite invisible, are playing an increasingly important role in the pollution problem of America.

CARBON PARTICLES

First, they serve as carriers of other substances. This is particularly true of carbon particles. Instead of being a solid chunk of matter, most tiny carbon particles consist of cage-like structures of extremely small primary particles chained together into a space-enclosing skeleton. Such particles are essentially inert, but they can serve as frameworks on which gases adsorb and other liquids and solids agglomerate. While carbon is probably a very important "getter" for gases and an effective nucleus for other liquid and solid particulates, a vast host of other substances behave in a similar manner or coalesce to form microscopic liquid droplets.

I am dismayed by the all pervasive bluish and greyish hazes that increasingly limit the visibility of distant hills and mountains and even the ground as seen from a high-flying plane. A particularly distressing feature of this hazy atmosphere is its uniformity and massive extent. I commonly notice it over at least half of the United States, and I am not surprised to see it on the continental scale. On transoceanic flights during the past six months — one to Japan, the other to Czechoslovakia — I have seen evidence that it may have reached global continuity, at least in the middle latitudes of the northern hemisphere.

The source of such widespread pollution is not easy to establish. It is now possible to fly over large cities such as Los Angeles without seeing a single visible smoke source. In fact, in recent years I have considerable difficulty to ascertain the direction of the wind at low levels as I could in the past by using smoke plumes as wind indicators.

Pollution control agencies have

POLLUTION RANGES
(Indicated by Condensation Nuclei)

Typical Source	Concentration of Particulates (per cc)	Degree of Pollution
Oceanic and polar air	Less than 1,000	Clean
Country air	1,000-5,000	Light
Suburban air	5,000-50,000	Medium
Urban and industrial air	More than 50,000	Heavy

succeeeded in eliminating nearly all visible sources of air contamination in many urban localities. Visible smoke sources are relatively easy to detect, and those responsible can be cited and penalized.

If most visible plumes have been eliminated, why are we confronted with an increasingly serious air pollution problem? The blame can be placed quite easily: Most of the pollution comes from effluents which consist of invisible particulate matter and accompanying vaporous gases which cannot be seen when they are released into the atmosphere.

It is easy to demonstrate this principle. If a large transparent plastic bag is placed over the exhaust pipe of an idling automobile, it will become full of an odorous effluent in a few seconds. This bag is now filled with air, water vapor, gases and particulate matter, the latter having a concentration of 10^7/cc or more. With a simple instrument, the concentration of small particles can be determined. Such a measurement shows that a typical idling automobile engine emits at least 100 billion small particles per second. Most of these particles are submicroscopic and invisible. However, if the bag is observed carefully it will soon have its inside coated with a dense layer of water drops and if some of the trapped effluent is transferred to a box made of clean sheets of glass and illuminated with a strong beam of light, such as a home movie or slide projector, a visible bluish or grayish shaft of scattered light will be seen. Because of the very high concentration of particles emitted by the idling motor, the original invisible particles have coagulated to form the now visible aerosol. Thus a measurement of the number of particles in the sample after 20 minutes will show a drop in concentration of a hundredfold as coalescence proceeds and the particles become visible by their scattered light. Very few particles fall out, however, since the effect of gravity on such small particulates is negligible.

As particles grow from their original invisible size range of 0.02 μ to the visible sizes of 0.1 to 0.4μ diameter (producing a bluish haze) their light-scattering effectiveness becomes quite noticeable, especially in the blue end of the visible spectrum. Such particles scatter almost as much light back toward the illuminating sources, such as the sun, as in a forward direction. This effectiveness in the scattering of visible light reaches a maximum with a diameter of about 0.6μ. It was this feature that caused us to produce particles of that size during World War II when we successfully hid our armed forces from surveillance and bombing at the Anzio beachhead in Italy and during the crossing of the Rhine River in Germany.

VAPORIZED PARTICLES

There has been a tendency on the part of some engineers and others to employ after-burners and similar devices to vaporize an effluent so that ordinarily visible emissions are reduced in size so as to become invisible. Where this is done in a manufacturing process, only a measurement of the stack effluent with a small-particle counter or observations by a careful observer will detect the subterfuge. Thus a plumeless chimney or clean looking jet engine or an automobile exhaust pipe does not necessarily mean that the removal of an offending pollutant has been achieved. In fact, I believe that in some instances the so-called improvement produces a worse situation than before.

One of the other subtle results of this shift from large to small particle size in the pollution production of a large city is that the "dust fall," high volume sampling and other measurements at ground and building top levels, will quite likely show a decrease from earlier measurements. This can be very misleading since the end results will be the extension of the effect of the city into regions down wind of the source. During the past few years I have seen the plume of the Los Angeles Basin area in such areas as the Owens Valley, the Mojave Desert, the Charleston Mountains in Nevada, and a few weeks ago in the vicinity of Palm Springs and Palm Desert. I have even observed pollution plumes from southwestern California near Spokane, Washington, and central Nebraska when carried by low level jet streams.

To measure such plumes, one must depend primarily on aircraft, although during my recent observations in California I was able to obtain data by direct measurements at the desert floor and on the slopes and near the summit of Mts. Baldy and San Jacinto. While the hot flame temperature needed to vaporize an otherwise visible effluent might achieve improved combustion, it also oxidizes some of the natural nitrogen in the air to produce nitrogen oxides. In addition to being poisonous, these gases are believed to be an important catalyzer for the photochemical reaction which converts hydrocarbon vapors to particulates.

When converting visible particles to invisible sizes, the residence time of such particles is also greatly extended. Thus a very large aerosol particle of say 50 microns (0.002 inches) diameter, if ejected into the atmosphere at the top of a 100 meter (300 foot) chimney would fall to the earth in less than 15 minutes. If such a particle was vaporized and then condensed so that the resulting particles were invisible (say 0.02 μ in diameter), a single 50 μ particle would produce more than 10 billion of the smaller size. Such particles would have a residence time in the atmosphere of months or years, depending on where they were carried by the wind or whether they were removed by precipitation. As mentioned earlier, gravity has little effect on such particles. They are primarily removed from the atmosphere by growing much larger through agglomeration (a very slow process), by the scavenging effects of snow or rain or by diffusion to various objects on the earth's surface.

If the vaporized particles recondensed to form a bluish smoke (0.2 μ diameter), a single 50 μ particle would produce about 10 million of the smaller size but they also would have a residence time in the atmosphere of weeks or months, unless removed by the processes just mentioned.

This points up one of the many problems which will develop when high-flying aircraft such as the supersonic transport (SST) fly in the stratosphere in large numbers. The stratosphere is a very stable region without benefit of a cleansing mechanism like snow or rain. We must consider the possible effect of large concentrations of small particulates and gases such as would be emitted into this region, and the effect of an accumulation of these aerosols on the present equilibrium of that region of the upper atmosphere. What will such pollutants do to the ozone concentration, the radiation balance and similar properties? Thus far I have not succeeded in obtaining satisfying answers to these questions.

The effect of small particles on health is becoming recognized. I have recently suggested that a possible additional hazard confronting the smoker is that air pollution particles passing through the burning zone of a cigarette are vaporized and the lungs then serve as a test tube where synergistic reactions can occur to form a myriad of exotic particles coating the surface of the entire respiratory tract. Thus the persons who smoke in urban air commonly insult their lungs with the vapor from at least 50,000 to 100,000 more particles per cc than produced by the burning tobacco.

This then brings me to my final point which is related to inadvertent weather modification. I am convinced that man-caused pollution has raised a host of new problems which I didn't contemplate when in the 1940s I was conducting my experiments of seeding supercooled clouds with dry ice fragments and other substances. Supercooled clouds were of common occurrence in the Northeast, and in fact we carried out more than a hundred experimental seeding flights in New York and New England between 1946 and 1950. Extensive areas of supercooled clouds were of common occurrence, and in our Project Cirrus activities we learned many scientific facts about the possibilties and limitations of cloud modification during that period.

I would be reluctant to conduct a similar research program in that same area at the present time. It is my experience over the past five years that extensive areas of supercooled clouds are of less frequent occurrence and that massive areas of ice crystals at low level are more frequently encountered than 20 years ago. These high concentrations of low-level ice crystals are so high as to produce brilliant undersuns such as we only saw during our early experiments in stable, heavily seeded areas produced by our experiments. (The undersun is an optical phenomenon caused by the specular reflection of the sun from the surfaces of myriads of hexagonal plate ice crystals. In order to produce an undersun, it is necessary for the crystals to consist of smooth-surfaced plates which float with their long axes horizontal to the ground. Thus they act as many tiny mirrors.)

Where are these ice nuclei coming from? I have presented my ideas on this source in several papers published in the scientific literature. I am not alone in my findings. Briefly stated, we have found abundant evidence that a potent source of ice nuclei is to be found in air polluted with automobile exhaust from leaded gasoline. Submicroscopic lead compounds apparently react with small quantities of iodine vapor to form lead iodide. These activated nuclei must be very small to be most effective since they apparently act as sublimation nuclei, i.e., the water molecules in the air form ice crystals directly from the vapor phase. If these particles were larger so that the water condensed to form liquid droplets, the lead compound would dissolve, destroying its effectiveness as an ice nucleus. The number of these potential ice nuclei in polluted air is from hundreds to a hundred thousand times more than is found in clean air.

I have also observed and photographed a great many examples of high concentrations of ice crystals in polluted air. Such areas are so extensive that I believe they could exert an effect on the weather patterns over America.

I previously described the misty rains and very light snows which I believe can be attributed to automobile pollution. An interesting and rather paradoxical effect can be postulated which suggests that a superabundance of effective ice nuclei over extensive areas could reduce as well as increase precipitation. High concentrations of ice nuclei would stabilize clouds containing low amounts of liquid cloud water and thus reduce or prevent precipitation. On the other hand, if a rich source of moisture moved into a region and entrained extensive areas of polluted air containing many potential ice nuclei, it could produce excessive amounts of snow or rain.

This is not to say that only pollution can cause a reduction or an increase in precipitation. What I anticipate, based on an increasing amount of cause and effect field observations I have obtained, is that the frequency of such unusual weather phenomena may increase as air pollution increases.

In conclusion, I would like to emphasize that we are dealing with an extremely complex problem which will require a much greater involvement of our total society than has occurred at present. The type of legislation required at the federal level must consider aspects of the problems that can't be solved by the individual states. I am sure that we must also establish global rules of conduct if we are to halt the rapid deterioration of the environment that has alarmed us.

I believe that the university community has an important role to play in solving some of these problems. It is heartening to see the way in which many young people in our universities are espousing the cause of environmental improvement. They are actively seeking education and guidance in their concern and have responded in a wonderful manner to our action programs.

The time is passing when the American community will tolerate arrogance, hypocrisy or cynicism on the part of anyone or any group whose activity will further degrade the quality of our environment. This is not a fad. Anyone who believes it is does so at his peril.

I am an optimist. Any system that can put a man on the moon in 10 years can certainly solve the technical aspects of our pollution problem. At the same time we must rethink our sense of values and probably reorder many of our current procedures so that together we can seek goals that are addressed to community well-being in every sense of the word.

L. C. BLISS

A BIOLOGIST EXPLAINS:

Why We Must Plan Now to Protect the Arctic

One of the key issues in the development of Arctic oil pools in the Prudhoe Bay region of Alaska is TAPS, the Trans-Alaska Pipeline System. The proposed pipeline would carry hot oil some 800 miles across frozen tundra and scrubland from the North Slope to the port of Valdez, on the Gulf of Alaska for transshipment. The ecological consequences of such a cross-country structure are discussed here by Professor Bliss, a botanist and director of the Controlled Environmental Facility, University of Alberta, Edmonton. This article is adapted from one published by the Canadian journal, "Science Forum."

The discovery of oil at Prudhoe Bay, Alaska, in January 1968 initiated profound changes in the North American Arctic. Many of these are economic, but of equal importance are the potential environmental changes. Until now the Arctic has been viewed by most people as a huge wasteland with a forbidding environment. Despite this harsh environment, the black gold stirs men to think of wealth, an ever-expanding economy, and the development of northern cities. While this pattern of 'development' may occur, its pace must be in keeping with that of environmental technology, and not geared only to the economic and engineering technology that for years have been the masters of men.

Until a few years ago feasibility studies for a new factory, dam, urban development, pipeline, or oil field seldom if ever considered environmental costs, for it was believed that through technology we had learned to conquer nature. The fruits of this philosophy have turned bitter with the pollution of our waters, agricultural soils, wildlife, and air, and the social and economic deterioration of many areas within large cities. We are learning from our past mistakes and there is the hope and expectation that this perspective, gained in temperate regions, can and will be utilized in our North. We must realize that the Arctic environment is far different from temperate regions and new technologies must be developed to cope with it.

One of the most characteristic features, yet one of the most serious deterrents to landscape modification in the Arctic, is permafrost. Permanently frozen ground, often extending to 500 to 1200 feet, covers the area beyond the treeline and also extends south in a discontinuous pattern within forested areas. This huge mass of frozen ground is a product of the Pleistocene Ice Age and the retreat of glaciers from these areas less than 7000 years ago.

Permafrost contains masses of ice as well as frozen soil and rock. Ice masses or wedges frequently 'grow' from year to year, resulting in ice mounds and polygons called patterned ground. These massive areas create few problems unless the thin but important insulative mantle of vegetation is removed. When this happens the ice melts and the ground slumps, forming thermokarst topography. The secret to successful activity in the Arctic has been to avoid disturbing the plant cover and to isolate man-induced thermal loads from the permafrost. When this has been ignored thermal erosion has occurred, often with disastrous results to buildings and roads. In summer there is sufficient thermal input through the vegetation to thaw the upper portion, called the active layer, to a depth of a few inches to several feet, depending upon amount and kind of plant cover, slope exposure and steepness, and the ice content and texture of the soil.

Although Inuvik lies within the area of scattered spruce and aspen trees, there is continuous permafrost on this river terrace above the Mackenzie. Thanks to the research of the building division of the National Research Council, it was known that buildings should be placed on stilts, and that utilities should not be buried but rather run above ground in insulated boxes called utilidoors. When buildings were erected, such as a new hangar at the Inuvik airport, great care was taken to ensure that permafrost would reform within the gravel around the supporting posts of the structure by isolating the hangar environment from the ground below. Thermocouples were installed to enable accurate measurement of the thermal regime below the building and the adjacent newly-surfaced runway and asphalt apron.

While these problems are large, they seem small in relation to those of oil drilling, pipeline laying, and road construction. The oil will come out of the ground at about 170°F and there are problems in isolating this heat from the permafrost. There is normally little problem in anchoring pipe casing in the ground, but in the Arctic the casing will heat up and melt the surrounding permafrost, which may result in blown casing and oil loss. Thus new casing designs are essential if oil pollution at the wells is to be eliminated.

The oil will be transported in

four-foot-diameter pipes, the largest yet used in the industry. These pipes will carry crude at a temperature of 160° to 170°, and due to thermal input at the pumping stations and friction along the line, oil temperatures will remain high. The estimates were that if the line was not insulated and was buried three feet below the surface, ground surface temperatures in summer would average 130° and in the winter 70°. Such surface temperatures are not conducive to plant establishment and growth when below-surface soil temperatures in summer are normally 35° to 55°. It would therefore be impossible to establish a plant cover on top of the buried line; the most appropriate procedure would be to cover the line with gravel. It is now recognized that pipe insulation is no solution to the problem of heat transfer.

TAPS

The proposed TAPS (Trans-Alaska Pipeline System) is projected to run from Prudhoe Bay to Fairbanks and south to Valdez on the coast. The route through the Arctic would follow the north-south rivers where possible; this is a good feature, for less environmental damage would be done if the line were placed within river-bed gravel. The dry permafrost of coarse gravel is a less hostile environment than that of the uplands, where ice content commonly runs from 30% to 50% and may reach 60% to 80%. Gravel is a good thermal sink because it contains little ice and its shape is not modified when the ice melts. In contrast, mineral soil with a high ice content slumps very badly when the ice melts, resulting in thermokarst topography.

For this reason the proposed pipeline would be elevated in areas of high ice content. The early estimates of 40 miles of elevated line have been revised to 150 to 200 miles. It must moreover be elevated sufficiently to permit large herbivores (caribou, bear, and moose) to move beneath it. There is no assurance that migrating caribou will cross under a line elevated eight or ten feet, or whether they will see it as a fence. They certainly would be blocked in their movements if the line were placed on top of the ground, as would the movement of all other flightless animals. Current studies show that caribou often will not even cross skidoo tracks in the snow; this phenomenon is used in rounding them up.

A. H. Lochenbruch, U. S. Geological Survey, has calculated that even if a pipe is insulated, the unit will rather rapidly come into thermal equilibrium and thus melting of the permafrost is inevitable. He calculated that thaw below the pipe would be about 26 ft. the first year and 49 ft. in 20 years. Lateral thaw would be of a similar magnitude. Thus the pipeline should be buried only in areas of coarse sands and gravels where ice content is very minor and its melt will not result in subsidance.

A construction and service road will be needed parallel to the pipeline. In most climates such roads present few construction problems, but in the Arctic there is a major one — again, isolation of the road from the permafrost below. The usual practice in road building is to remove the vegetation and finer-textured soil and then build with gravel. But in the Arctic the vegetation cover must be kept intact, for it is an excellent insulator. Thus gravel must be poured over the vegetation, or possibly over an additional artificial insulative layer. This practice has been developed in the construction of the Dempster Highway north of Dawson City by the chief highway engineer, Harry Trueman.

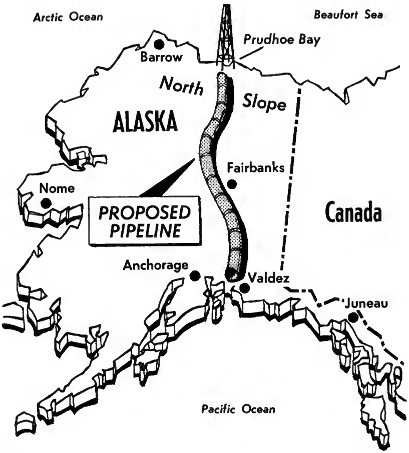
If the gravel road runs in the valleys next to the pipeline it will be unavailable for use during the spring ice breakup, and portions of it will be washed out each year with spring flooding. If the road is built in the rolling terrain above, frequent road spurs will need to run to the line below, and this will result in further potential thermal and water erosion. Again these problems are minor in temperate regions where the bulldozer and power saw are used freely. In the Arctic every surface disturbance can lead to serious erosion and to added costs for repairing the vegetative damage. Oil companies with foresight are now reducing the potential damage to the tundra by restricting vehicular traffic to winter when the surface is frozen. They are also developing vehicles with huge balloon tires to reduce the contact weight with the surface and thus reduce the dangers of pulling out or damaging the plants. In addition the turf is frequently replaced when it is broken. Without such practices, caterpillar tractor tracks have remained visible for more than 20 years, and bulldozer activity that has opened up the permafrost has resulted in more than 20 feet of lateral thermal erosion in two summers.

The fragility of tundra vegetation is well illustrated by the activities of man and dog on Garry Island in the Mackenzie Delta. After Dr. Ross Mackay and his associates from the University of British Columbia used a walking trail for three summers, a gully developed one foot deep at its upper end and five feet deep at its lower end near the shore. A dog tied to a stake for less than a month made the ground surface drop by one foot because the vegetation was disturbed and solar radiation could melt the upper permafrost ice. Our own research this past summer showed that if we walked across sedge tussocks a few times they became matted and brown. This can lead to increased summer thaw due to changes in albedo.

Plant growth in the Arctic is very slow because of the low air and soil temperatures and limited available nutrients, and thus erosion and slumpage exceed the ability of plants to revegetate the disturbed surfaces.

FURTHER PROBLEMS

The pipeline faces further problems in crossing the Brooks and Alaska Ranges: it will require rock blasting, with associated erosion and it will face a harsh environment at the relatively high elevations of the passes. Once the line is south of the Brooks Range, forest predominates, but even there permafrost is common so that the problems of thermal erosion will continue. Furthermore, as the line nears the south coast it will enter Zone 3 of earthquake frequency. This means that the probability of earthquake rupture to the line and to storage tanks at Valdez will be very high, especially considering that the Arctic fields and lines are ex-



pected to function for 20 to 30 years. Oil spillage would obviously damage wildlife, vegetation, and soils, yet there is little research to show exactly what the effects would be, nor how to clean up the oil efficiently so that as little environmental damage as possible would occur.

Oil inevitably will be lost into the port at Valdez as ships load. Supertankers will be damaged and sink if they are used. This is inevitable because tankers sink everywhere they are used, and the Arctic presents even greater than normal hazards. The oil will destroy birds that become coated, tidal zone invertebrates, insects, and other invertebrates that help decompose seashore organic matter. These reductions in animal and plant populations will affect other levels within the food chain, so that we can expect reductions in populations of polar bear, seals, walrus and fox.

The probability of tankers sinking in the Arctic can be judged from the fact that in the past five years 94 tankers have sunk elsewhere in the world. The most publicized was the Torrey Canyon in 1967; claims for the pollution of beaches in England and France resulting from that disaster have been only recently settled. In December the new supertanker Marpessa sank on her maiden voyage, fortunately without oil. Early this spring the Arrow sank off the coast of Nova Scotia and the cost of cleanup was very great as was the cost in loss of animal life. These sinkings plus continued oil leakage in the Santa Barbara channel and the flushing of tanker storage compartments results in over 270 million gallons of spilled oil per year. The California offshore leak has now spread oil 100 miles away to the Santa Catalina Islands and, ironically, polluted an ecological study site set up because of the previous lack of pollution in that site. Such accidents are bound to increase in the future unless strict regulations are passed and enforced.

The problem with Arctic oil spillage is that it will last for years in the ice pack and its effect on wildlife and marine algae cannot yet be properly estimated. The effect could be severe if oil reduces the rate of phytoplankton production, for this would lower production of all other food chain levels. The Arctic seas now are quite productive of fish, due in part to the upwelling of waters which makes more nutrients available for photosynthesis by algae.

An interesting aspect of the TAPS line and the tankers linking it to Seattle or San Francisco is that they will deliver the oil to areas where there is little oil deficit. Thus another large pipeline will have to be laid to the Chicago area where the oil deficit occurs.

An alternative to the pipeline-tanker proposal is the use of supertankers to transport oil to European and east coast ports. The first voyage of the Manhattan in 1969 (a second has just been completed) was supposed to prove the feasibility of this route. It was far from a success: icebreaker help was frequently needed, and the ship could not pass through McClure Strait due to ice ridges but turned south through the more ice-free Prince of Wales Strait. Also the Manhattan sailed the Northwest Passage in the most favourable time of year and in the best (most ice-free) summer in more than 50 years. In spite of all of these favourable factors her hull received two large holes, which hardly suggests this could be a year-round oil transportation route.

Many Canadians have spoken of the fear of foreign ships using the Northwest Passage through sovereign waters. As a biological rather than a political scientist, my fears are more of the national and international problems of regulation and law enforcement resulting from pollution and ship salvage in Arctic waters. These problems can be worked out before they occur but they require national and international action now.

Even if tankers could make the passage throughout the year, there are problems of harbour development. These tankers are huge and the continental shelf in the North is near the surface, so tankers will have to anchor 10 to 20 miles offshore unless a harbor is built on Herschel Island where water is deeper. However a 'harbour' is handled, there will be the problem of laying the pipe from shore out to a loading dock. Near the shore the pipe will have to be well buried to avoid the crushing action of onshore ice movement. The technology has not been worked out yet for cutting out blocks of permafrost inshore, nor for welding sections of pipe on land or water since a relatively uniform pipe temperature is necessary to avoid differential contraction. These problems can and will be surmounted by engineers, but it will take time, for again many of these conditions have not been encountered before.

A third route of oil transport is being considered by the oil industry, but it has received less attention. The Mackenzie Valley Pipeline is proposed to run from Prudhoe Bay, east to the Inuvik area and south to Edmonton and hence to the Midwest via existing and expanded pipelines. This route has the disadvantage of crossing the Arctic Wildlife Range which would require approval of the Department of Interior, which will not likely be forthcoming since the range was set up to preserve a large piece of Arctic landscape and its biota.

LESS COSTLY

One advantage of this route is that it would permit oil from the new field discovered in the Mackenzie Delta to be transported by the same system to the markets. This route moreover would deliver the crude to the oil hungry Midwest, and at an estimated cost that is considerably less than through the other routes.

The estimated per barrel costs to get the oil to market are $1.10 via supertanker to the east coast, $1.00 via the TAPS line and tanker to Seattle and then pipeline to Chicago, vs. only $0.55 via the proposed Mackenzie Pipeline to Chicago. It should be obvious that the latter route will receive more attention in the future. The danger of this approach is that, if agreed to, a four-foot line will be built now, to be followed in the future by a gas line. In terms of impact on the landscape it would be far better to sort this all out initially rather than to take the usual piecemeal approach which can devastate an Arctic area by repeated disturbance for new lines.

An injunction has been placed on the construction of the service road of the TAPS line and this will probably lead to court hearings, which should have been held in the first place. The fact is that no decision on transportation routes should be made until more facts are known about the engineering technological feasibility and environmental cost of each method. It may well be that the Mackenzie Route is best, but that the pipeline would skirt the Arctic Wildlife Range on the west and south. This would add to the costs of the line and necessitate running a spur line north to the Mackenzie Delta, yet environmentally it may be the best solution. However if the total environmental damage would be significantly greater than from running the line across the Wildlife Range, then the latter route must be seriously considered. If this route were approved it would be essential to prohibit any other pipelines, roads, or wells to be developed in the range. The danger of this decision would be the future economic and political pressure applied to develop oil wells within the range, a situation that should not be permitted to arise.

Arctic Eskimo and wild animal populations will face new problems with the increased activities of oil and mineral exploration and extraction. Large tracts must be set aside as has been done in Alaska, the Arctic Wildlife Range, and elsewhere, where stringent restrictions on hunting are enforced, if we expect to maintain population of caribou, muskox, wolves, bear, and moose. In coastal waters seal, walrus, and whale hunting by Eskimos is reduced when European man moves in. The native people at Tuktoyaktuk report that whale hunting was greatly reduced this last sumer due to the activity of people and boats in the area.

In the Mackenzie Delta and other river basins that enter the Arctic, large populations of beaver and muskrat have been an important source of income to native peoples. Water pollution and silting, cutting of timber, and other activities threaten to greatly reduce this important biologic resource and thus decrease the economic stability of these people.

Large areas in the Arctic are covered with fresh water in summer. These marshes and lakes are the most important breeding ground for many waterfowl, and the continued maintenance of these populations as a biologic and hunting resource must be weighed against their loss due to potential pollution and land drainage. These activities will also affect many species of fish.

It is inevitable that some animal populations will be reduced as man's activities increase. The danger is that in many areas species will be eliminated unless decisions are made soon to maintain favourable habitats in what until now has been a huge area with relatively little exploitation. Land use patterns and wildlife resources will change greatly within three to five years unless the federal government and interested conservation groups act now.

UPWARD SPIRAL

The combination of the world's thirst for oil and the tremendous costs of exploration, land leasing, field development, and transportation has resulted in great pressure to develop oil fields as rapidly as they are discovered. The product of these practices is a continued upward spiral in the production of internal combustion engine vehicles and the inefficient use of our fossil fuels which has resulted in the atmospheric pollution of all large cities with a high vehicle density.

The decades of the 50s and 60s will go down in history as a period of rapid industrial expansion and a corresponding explosion of the world's population. This combination has resulted in an increasing gap between the over-developed and the under-developed countries and the pollution of the water, soil, air, and wildlife of nearly all areas on earth. One of the most serious dangers to future generations is the lack of clean air in our cities. The most guilty culprit is the internal combustion engine. The decade of the 70s will be remembered as the period in which environmental quality and population control problems received high priority in all countries.

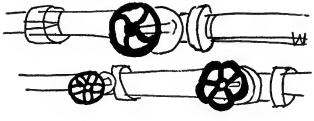
We find ourselves in a real dilemma today. We know that automobile exhaust is the major air pollutant, yet we continue to look with favour upon increased automobile production, the discovery and rapid development of new oil fields, and the building of more refineries and highways. The end product of this chain of events is a continued rise in highway injuries and deaths, larger piles of auto junk, more superhighways within cities displacing people and open space, and more air pollution. The solutions to these problems are not simple and in part they require a new economic philosophy.

In less than 10 years we will be condemned for wasting these most valuable hydrocarbons as fuel rather than using them over the long term in the plastics, food, and drug industries. In 1969 the United States consumed over nine billion barrels of oil and it is estimated that by 1980 the demand will have doubled. Project a doubling of the current problems associated with cars, freeways, people, and air quality and the fiction of 1984 takes on a sobering twist.

It is to be hoped that man will move on all fronts to counter this movement. Several projects have already been initiated. Henry Ford has announced that the Ford Motor Company has developed an exhaust anti-pollution kit for cars that can be installed for approximately $50. These should be made mandatory for all cars.

All major cities should develop public mass transportation systems and ban most cars from the downtown areas. Cars should be built to last 10 to 15 rather than two to five years. The ownership of a second or third car should become a stigma rather than a status symbol. Combustion engines should be greatly improved in their use of fuel and other engines developed to replace them. Finally, governments and society must insist that when oil fields are discovered they are not harvested until really needed, and that much of the crude be used for uses other than fuel.

These changes are major ones and they will require a new set of values among companies, their stockholders, and society at large. Yet it is clear that our current rate of resource harvest, urban sprawl, and priorities cannot continue at the present pace for the next decade. Our time for decision is rapidly running out.



Fortunately there are signs of hope, even if small. The Canadian and United States governments now recognize the need for maintaining environmental quality in the Arctic and in temperate regions as well. Prime Minister Trudeau has taken a courageous step in claiming Canadian jurisdiction over Arctic waters for the enforcement of pollution control. The Department of Indian Affairs and Northern Development is developing regulations for Arctic oil exploration, oil field development, and pipeline construction. President Nixon has recently signed into law the establishment of a Council on Environmental Quality on a par with his Economic Council. I hope our government will recognize a similar need.

Turning-points were reached at the Alaska Science Conference at Fairbanks in August and the Tundra Conference at Edmonton in October 1969. At both conferences people from industry, government and universities came together to discuss problems of the North. If nothing else they at least enabled people with different philosophies and motivations to discover the views of others. Resolutions dealing with Arctic conservation were passed at the Edmonton meetings. These resolutions and others may begin to have an influence on the development of northern regulations for the maintenance of environmental quality. It is essential that sufficient communication occur between the Departments of Indian Affairs and Northern Development and the U.S. Department of Interior in the development of regulations for Arctic resource management, since the environmental problems are the same in both countries.

Industry realizes that maintaining a favourable environment for man is important to its stockholders and economic future. It costs less to prevent environmental catastrophes than to cure them. Thus we have moved into an era of discussion and joint planning by government, industry, and environmental scientists. The oil industry is concerned about land use practices in the North and has formed a general pollution committee within the Canadian Petroleum Association. These companies recognize that their practices must be modified in order to lessen environmental damage, and that ecological research must be conducted to determine the stress limits of animals and plants. To this end research studies on land surface disturbance are being started this summer in the Mackenzie Delta with the financial support of the Government and industry. This research, conducted by university researchers, is coordinated through the Department of Indian Affairs and Northern Development. Additional studies on surface disturbance and the functioning of an arctic ecosystem are being initiated on Devon Island with the basic objective of determining how a natural system functions and how far it can be stressed, yet kept functional.

Seeking the counsel of ecologists to help solve environmental problems is a significant move by governments and industry alike. There is a long hard road ahead, but the 70s will be recorded as the turning point in the recognition that man is a part of his environment and that he must function as a steward rather than a conqueror of nature. Most of our environmental mistakes have been made in temperate regions. While we do not have all the answers, we have enough to know how not to repeat this in the Arctic. The question remains, will we? The jury is still out.

DONALD F. ANTHROP

Environmental Side Effects of Energy Production

Looming ever larger among the proliferating and deepening crises of our ecosystem is the fundamental one of energy sources. As power companies move from fossil fuels to nuclear energy, society faces new kinds of pollution and new production problems. The question raised here is: Do we really need so much power? Donald F. Anthrop is assistant professor of geography at California State College, Dominguez Hills, California.

Considerable controversy has arisen in recent months over the siting of electric power generating stations and the environmental effects of energy production. The Los Angeles Air Pollution Control District has prohibited the Department of Water and Power from constructing any additional fossil fuel power plants in the Los Angeles basin because the nitrogen oxides emitted from such plants contribute significantly to photochemical air pollution in the basin. New York's Consolidated Edison has been stymied, at least temporarily, in its efforts to build a generating plant at Storm King on the Hudson. And Florida Power and Light's planned expansion of the Turkey Point facility by the addition of two nuclear generating plants has stirred increasing opposition because of the resulting increased thermal pollution of Biscayne Bay.

The electrical utilities argue, however, that major expansion of power generating capacity is needed to meet the growing demand for energy and that this expansion can be carried out without significant degradation of the environment. This view is well-illustrated by a recent editorial in "Science" written by former American Electric Power Co. president Phillip Sporn, who stated: "And if this opposition to expanding our electric energy supply continues, surely we are going to bring about a catastrophic situation. This we simply must avoid. The implication this carries for our national policy is clear. A major effort is called for to make possible continuing and expanding use of energy by man and to assure compatibility of this energy with a healthy environment."

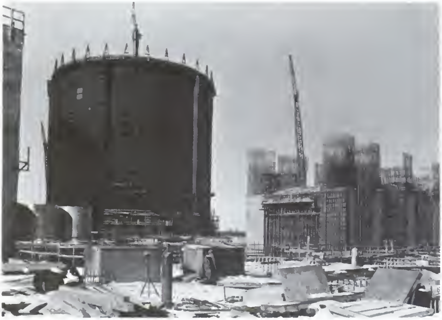
As we shall see, however, the growth in energy consumption that has characterized the past three decades cannot continue without some very deleterious effects upon the environment and, in fact, the "catastrophic situation" may well arise as a result of the continuing increase in energy production rather than opposition to it.

ELECTRICAL ENERGY

Electrical energy production in the United States increased from 180 billion kilowatt hours (kwh) in 1940 to 1,433 billion kwh in 1968. The average annual rate of growth during this 28-year period was 7.41 per cent, while population growth averaged only about 1.5 per cent annually. However, per capita consumption increased more than fivefold during this period. These numbers should not be construed to mean that population growth was unimportant, for as we shall see, population growth has been partly responsible for the increase in per capita consumption.

During the 11-year period 1955-66 the average annual rate of growth of electrical energy production was a slightly lower 6.4 per cent. At this rate of increase, electrical energy production doubles in just under 11 years; and if even this lower rate of growth were to be sustained for the next 30 years, American society would be consuming 11.0 trillion kwh of electricity annually at the turn of the century. If, in order to minimize the number of sites required for power generating plants, the additional generating capacity required to supply this energy were provided in the form of 4,000 megawatt electrical (MWe) plants, 503 such plants would have to be built. Now a 4,000 MWe plant is an exceedingly large one, much larger than anything in operation today. At its controversial Diablo Canyon site on the California coast in San Luis Obispo County, Pacific Gas and Electric is constructing an 1,100 MWe plant and an application has been filed for construction of a second identical unit which would give a total capacity for the site of 2,200 MWe. The huge Navajo generating station, being built by a consortium of utilities and the Bureau of Reclamation near Page, Arizona, will have a total capacity of 2,300 MWe.

Construction of power plants with capacities of this magnitude has serious implications for the ecology of the freshwater or marine systems in which the waste heat is disposed. Fossil fuel steam generating plants convert only 30 to 35 per cent of the total thermal energy into electricity. The remaining 65 to 70 per cent must be dissipated, usually in a body of water. Nuclear plants are considerably less efficient and are unlikely to match the efficiency of fossil fuel plants within the next 20 years. Thus, dissipation of waste heat becomes a very serious problem. The Navajo plant will use cooling towers in order to avoid returning large volumes of hot water to Lake



Commonwealth Edison's Zion (Illinois) Station, under construction.

Powell, the source of its cooling water. This technique will result, however, in the evaporation of about 30,000 acre-feet of water annually in a region that already suffers a chronic water shortage.

WASTE HEAT

Looking then to the year 2000, one discovers that the waste heat that would result from the production of 11.0 trillion kwh of electrical energy would be sufficient to raise the temperature of the total annual freshwater runoff from the conterminous United States by 24°F. Quite clearly, even if 11.0 trillion kwh were to be produced in the year 2000, only a fraction of this power could be generated at inland sites. And the situation, in fact, is much more serious than even these numbers suggest. The difficulty is that this freshwater runoff fluctuates widely during the year. The Hudson River, where some 3,000 MWe additional generating capacity is planned within the next few years, is an excellent example. Freshwater inflow into the lower Hudson fluctuates between spring maxima as high as 40,000 cubic feet per second (cfs) and summer minima as low as 2,000 cfs. If the flow were 40,000 cfs, the waste heat from a 3,000 MWe plant operating on a daily average at 55 per cent of its capacity would be sufficient to raise the temperature of the river only about 1.5°F. Since the period of peak runoff occurs in the spring when the water temperature is low, the probability of a 1.5°F. temperature rise causing any significant ecological disruption would appear small. In late summer when the water temperature is already quite high and flow is low, the picture is very different. If the flow is only 2,000 cfs, the waste heat would be sufficient to raise the water temperature by 29°F. In actuality the temperature rise would not be that great because part of the heat would be dissipated through evaporative cooling. Nevertheless, the ecology of the river would unquestionably be seriously disrupted.

Coastal siting of power plants would undoubtedly result in less ecological damage than inland siting on freshwater streams. But limits are quickly reached here, too, as we can see by examining the situation in California.

During the 16-year period 1950-66 electrical energy consumption in California increased at an average annual rate of 8.8 per cent. The fact that this rate of increase was higher than that for the United States can be attributed in part to the higher population growth rate in California. Yet despite the fact that California's population growth rate began to decrease in 1964, the growth rate of energy consumption had not yet started to decline in 1966. If this 8.8 per cent annual rate of increase in electrical energy consumption were to continue until the turn of the century, California would need 92 additional 4,000 MWe power plants, one for every 10 miles of the California coastline. Even if these plants were to be clustered into what Alvin Weinberg has called "nuclear parks" of perhaps 40,000 MWe capacity each, nine such sites would be needed, and there would be an additional environmental "cost" in terms of aesthetic loss resulting from the necessary transmission lines from these very large plants. The 2,300 MWe Navajo plant alone will require construction of some 800 miles of 500 kilovolt transmission lines to carry power to the participating utility districts. Incidentally, 500 kilovolts is 45 per cent more than the voltage of any underground transmission line that has been built. While this power could, in principle, be transmitted underground at a lower voltage, the cost of doing so would be high. If society is willing to pay this cost, then it may also be willing to pay a different kind of cost, namely that of reducing its appetite for power.

TOTAL ENERGY

Although most of the current controversy concerns electrical power generation, electrical energy consumption is just one aspect of the increasing use of energy. Between 1940 and 1968 total energy consumption in the United States increased at an average annual rate of 3.41 per cent. Part of this increase was a direct result of population growth which averaged about 1.5 per cent annually during this period. However, per capita consumption increased from 6.0 kw in 1940 to 10.4 kw in 1968, a per capita consumption equivalent to about 12 tons of bituminous coal per year. Furthermore, although the rate of population growth has been declining in recent years, that of energy consumption has been increasing. During the five-year period 1963-68, the annual rate of population growth averaged only about 1.1 per cent, while energy consumption increased at an average annual rate of 4.5 per cent.

If even the 3.41 per cent annual rate of increase in energy consumption that existed during the 28-year period 1940-68 should continue for the remainder of this century, U. S. energy consumption in the year 2000 would total 543 x 10^{11} kwh, nearly three times what it is today, and per capita consumption would be 22.4 kw. If per capita energy consumption in the United States should indeed reach a level of this magnitude, then we would find ourselves in an extremely poor position to argue that other nations of the world could not also indulge themselves in a similar fashion. Yet, they probably cannot. Present world population stands at about 3.55 billion and if the current growth rate (1.9 per cent annually) were to continue, world populations at the turn of the century would total 6.4 billion. The United Nations median estimate for the year 2000, which allows for a declining net rate of growth, is 6.1 billion. A world population of 6 billion having a per capita energy consumption of 22.4 kw (the equivalent of 33 tons of coal per person per year) could exhaust the world's total recoverable coal resources of approximately 8,400 billion tons in less than 50 years, if coal were used as the only source of energy. It would matter very little, really, whether this resource became depleted in 50 years, 100 years, or 200 years. The essential point is that man has the capability of inadvertently altering the world's climate through the release of approximately 20 trillion tons of carbon dioxide into the earth's atmosphere. If the present partitions of carbon dioxide between the atmosphere and the oceans remain the same, atmospheric carbon dioxide could be increased by a factor of about four.

The characteristic American approach of seeking a technological "fix" for such problems is unlikely to provide workable solutions for very much longer. Technological means for capturing the carbon dioxide produced by fossil fuel combustion of the magnitude envisaged here are not available, nor are any such methods foreseeable.

Nuclear power generation offers the possibility of providing very large quantities of energy without increasing the carbon dioxide content of the earth's atmosphere, but it is beset with many difficulties. All of the civilian power reactors in operation in the United States are so-called "burner" reactors: that is, they consume uranium-235. If energy consumption continues to increase as projected, and if this consumption is met solely by power supplied from nuclear burners, the high-grade, low-cost uranium resources could be exhausted within half a century.

Breeder reactors offer a way out of this difficulty since they would enormously increase the nuclear fuels available for energy production by converting nonfissionable uranium-238 to fissionable plutonium-239 or by converting nonfissionable thorium-232 to fissionable uranium-233. But while feasible in principle, breeder reactors present some extremely formidable problems. The total U. S. energy consumption of 543 x 10^{11} kwh projected for the year 2000 would require the continuous production of 6.2 billion kw of thermal energy. If this thermal energy were to be produced by nuclear reactors, and even if one assumes the reactors to be clustered in "nuclear parks" of 40,000 MWe capacity each, located on the seashore, about 65 such facilities would be required. The approximately 11,000 megacuries of long-lived radioactive isotopes that would be produced each year would have to be somehow transported between the reactor site and the processing plant and ultimately stored at a disposal site. Furthermore, the magnitude of the thermal pollution problem that would result from the discharge of approximately 4.6 billion kw of waste heat into the marine or freshwater system used for cooling would be even greater than that previously discussed in connection with electric power generation.

POWER NEEDS?

The fundamental question which must be faced and faced very soon is: Do we really need so much power? To a considerable extent, energy can be converted into other resources. Thus, if there is a need to grow more food, it is possible, in principle, to irrigate land that otherwise would be unsuited for crop production provided there is fresh water available. If fresh water is not available, it is possible to desalt seawater and transport the resulting fresh water, across mountains if necessary, to irrigate the land. Both of these processes require the expenditure of additional energy. Also, if the supply of high-grade iron ore is exhausted, it is possible, by expending additional energy, to convert low-grade ore into iron. The United States is passing from a position of being a resource-rich nation with a low population to that of a resource-poor nation with a much higher population. For this reason, the increasing population affects the consumption of energy to a much greater degree than the population growth rate would indicate. Thus any program to control energy consumption must also have as its goal the termination of population growth.

Another factor, which has been at least as important to the increasing consumption of energy as population growth, has been the American tradition of growth for the sake of growth. The mountains of garbage and junked cars that litter the countryside represent not only wasted materials, but wasted energy. Malcolm Peterson, writing in a recent issue of "Environment," noted that production of a ton of steel from ore requires an energy equivalent of 2,700 kwh while this same ton of steel can be made from reclaimed steel in an electric furnace with an energy expenditure of only 700 kwh. The brightly lighted billboards and neon signs that line our streets and highways not only blight the landscape, they waste power.

In summary then, the environmental implications of continued growth of energy consumption are evident. Clearly, the phenomenal growth in energy consumption which has characterized the past three decades must eventually cease, for there are limits beyond which the world ecosystem cannot be pushed. The choice that the American people must make very soon is whether they wish to live within a reasonable energy and resource budget or suffer the environmental consequences of a continuation of the present trend. Unfortunately, very little time remains in which a choice is even possible.

GEORG A. BORGSTROM

THE DUAL CHALLENGE OF HEALTH AND HUNGER: A GLOBAL CRISIS

Some scientists and many politicians believe the Green Revolution to be accomplished. But two facts are often overlooked: more, not fewer, people suffer from malnutrition every year, and this circumstance prevails at a time when agricultural technology has already made impressive strides. The author, professor of food science and geography at Michigan State University, is the author of "The Hungry Planet" and "Too Many." This article was published earlier this year by the Population Reference Bureau, Inc., Washington, D.C., and is used here with their permission.

If all food in the world were equally distributed and each person received identical quantities, we would all be malnourished. If the entire world's food supply were parceled out at the U.S. dietary level, it would feed only about one-third of the human race. The world as a global household knows of no surpluses, merely enormous deficits. Yet there is in the well-fed nations a great deal of nonsensical talk about abundance.

Already short of food, the world is adding 70 million people to its feeding burden each year—the equivalent of an entire United States every three years. The annual increase is itself growing at a rapid pace; it is outstripping the gains in world food production despite all the triumphs of agriculture and fisheries since World War II.

THE HUNGER GAP

It is not enough to talk about absolute deficits, however, for the world's food resources are distributed with great unevenness. Over 2 billion of the world's 3.5 billion people live lives dominated by extreme shortages of food and water and by inadequate resources in soils and forests. These billions lack satisfactory shelter, clothing, education and medical care. In sharp contrast to their misery, a Luxury Club of at most 400 million people enjoys a rich and steadily more abundant diet as well as a high standard of living in most other respects. Between these two extremes are hundreds of millions of people who may be designated as fence-straddlers. They manage well enough despite numerous handicaps and limited resources, but their diet, although barely adequate, is monotonous and their life, in general, parsimonious.

The richly endowed are found in the United States and Canada, parts of Western Europe, Australia, New Zealand and the La Plata countries of Latin America. The Russians, East Europeans and Japanese belong to the in-between group. Asia, Africa and most of Latin America, with a combined population of more than 2 billion, are the most critical hunger areas. Their human numbers are increasing more than twice as fast (in per cent) as those of the well-fed world.

The widening hunger gap is an ominous feature of our days. It poses the greatest challenge mankind has ever faced, overshadowing atom bombs, continental missiles, microbial toxins and nerve gases

Despite courageous efforts by devoted groups, this crisis has not yet received the attention it desperately needs. Timid bureaucracies are caught in a striking discrepancy between thought and action. Although mankind is "hitting the ceiling"—reaching the limit in its use of the vital resources of soils, water and forests—it is quite obvious that nowhere in our population control measures have we moved beyond the very limited tactic of family planning. True population control in the sense of a deliberate effort to bring down birth rates has hardly anywhere been adopted. Limiting our efforts to averting "unwanted" children, however, is wholly inadequate. Studies show that even if successful, such a policy would have only marginal effects on world population growth by the year 2000.

The most disquieting aspect of the food issue is the fact that, with few exceptions, the scientific and technical community has been signaling a green light to mankind when a stop sign would have been far more appropriate. Recent statements by leading Western scientists in almost all disciplines reveal a shocking disregard for the abject conditions which enclose almost three-fifths of the human race.

It is indeed macabre to witness the present game of calculating how many people the world could nourish—if. The figures soar beyond 7 billion to 10 billion and even more. Yet, scandalously, the world has failed to provide satisfactorily for even half the 3.5 billion people alive now. To give our current population a minimally sound diet would require the immediate doubling of world food production. Thus, whatever else happens and whatever urgent measures are taken, food is going to be the overriding issue of the next 30 years.

Few undertakings in human history have had a greater impact than the enormous, prolonged effort to Europeanize the world. The psychological investment in this drive may explain both the West's lofty promises of abundance for all men and its complete misjudgment of mankind's true situation. In truth, the white man's experience has been misleading. No group of individuals ever seized a greater booty than did the Europeans who took possession of the vast forests and rich prairie soils of the North American continent. Unassuaged, the white man also grabbed the fertile pampas and most other good soils in Central and South America, the South African veld and the rich highland plateaus of interior Africa. He managed to gain control of an entire continent, Australia, with its valuable satellite, New Zealand. In addition, he secured strongholds all over Asia where he monopolized trade and to a considerable degree controlled agricultural production, making India British and the East Indies Dutch.

World War II ostensibly brought an end to this era in geopolitical relations. But as late as 1939, shipload after shipload of groundnuts left starving India to fatten the cows of the British Isles. Hundreds of millions of people in Asia and Africa have since attained independence. Superficially, world food markets have adjusted to this fact. More than 25 million tons of grain are now moving from wealthy areas to feed the hungry—as against the latter part of the 1930s when 11 million tons of cereal grains were dispatched from the hungry world to provide for the well-fed.

The monopoly of the European tribe, however, is still strong in the economic field. While public attention is focused on grain, let us direct the searchlight to other commodities and especially to proteins. Here the West finds no cause for self-congratulations. The almost 3 million tons of grain protein recently contributed to the poor nations by the rich and well-fed have been more than counterbalanced by a flow to the Western world of no less than 4 million tons of superior proteins in the form of soybeans, oilseed cakes and fish meal. The West is benefiting from a most deceptive exchange.

Thus, although it has far greater per capita soil and water resources than the hungry world, the West is tenaciously intruding on the latter's struggle for subsistence. Hundreds of millions of people in the tropics must limit their harvests for domestic consumption in order to raise export crops (groundnuts, cotton, coffee, tea and cacao, etc.) for foreign currency. This situation is further aggravated by the fact that the cash crops now enjoy a high priority with regard to credit, fertilizers and irrigation. Their fortunes in the world market, however, are declining. Since 1952 the developing nations have been delivering about 33 per cent more tonnage in cash crops while registering only a 4 per cent gain in income. Prices, of course, are largely controlled by the West. These somber facts help explain the collapse of two U.N. Conference on Trade and Development conferences, both of which ended in solemn pledges by the rich countries to devote a mere one per cent of their gross national product to the dire circumstances of the needy. Not only have most industrialized countries failed to live up to this meager commitment, but the percentage of GNP which the United States parcels out as "aid" has actually been declining.

A Hong Kong mother feeds her child.

The great good luck of Western man in the lottery of history underlies his profound belief that technology will bestow a universal abundance. Good luck has also made him complacent. He imagines that he is more capable than the poor and the hungry. He blames them for listlessness, apathy, laziness, inefficiency, lethargy, resistance to change, notorious backwardness and wavering creativity. In his self-deception he forgets that the ancestors of today's poor and hungry peoples created a host of great civilizations which, with an improvidence much like his own, wore out their soils, and forests.

In his imagined superiority, Western man chooses to label this hungry world "underdeveloped." If it were not for his historical oversight, he would find "overdeveloped" a more appropriate term. The overwhelming majority of the underfed live in countries where the soil has been over-cultivated for thousands of years, where forests have been pulled down in the erroneous belief that this act would best provide for ever-growing populations, and where water reserves have been exploited to the utmost.

We should not underrate the ingenuity of Asian, African and Latin American societies which not only survive but slowly advance under these conditions. With the meager resources available to them, many farmers in India and other parts of the so-called underdeveloped world display outstanding efficiency. Throughout Asia and Latin America, one can find an astonishingly thorough use being made of available land.

MINI-PLOT FARMERS

Hundreds of millions of hungry people live in the tropics, where farm acreages are exceedingly small and constantly fragmented through inheritance. Often it is possible to see original two- to four-acre holdings which have been subdivided into five or more plots. Though large-scale increases in production are difficult even on the poor world's "latifundia," we naively expect the "mini-plot" farmers of Asia, Africa and Latin America to triple or quadruple their production within three decades—something the Western world has never been able to do with all its immense resources of enriched soil and ample land.

The soils from which the poor nations must feed their people are often far inferior to those of the West's "marginal" lands, which are now being abandoned by agriculture. Water is also a scarce commodity in most regions of the hungry world, and agriculture is subject to many more vagaries of climate than in the temperate regions. Moreover, the farmer in a poor nation usually lacks capital for expanded irrigation, for fertilizers, for better sprays against insects and fungi. The handicaps he faces are so severe that any comparison with farmers in the West is absurd.

I could delve at great length into the human consequences of this situation but will limit myself to a few remarks about the relationship between health and hunger. A great many people in this world are hungry or malnourished all of the time or part of the time. How is their working capacity affected? And what does an insufficient diet do to their overall health?

The prime global deficiency is that of protein. Until recently this fact was grossly neglected by experts who measured tonnages and profits but who limited their nutritional considerations to calories. Indeed, 10 to 15 per cent of the world is short of calories, or "undernourished." But vastly more people—perhaps 1.5 billion—suffer from the calamity of inadequate nutrients, or "malnutrition." A shortage of protein is the number-one problem everywhere in the hungry world. Many other deficiencies related to shortage of fat, minerals (calcium, iodine, etc.) and vitamins (B1, B6, folic acid, vitamin A, etc.) are also quite common, and as the hunger problem broadens, these and other dietary shortcomings will greatly assert themselves.

TELLING EXAMPLES

Today a wealth of documentation confirms the existence of a nutritional crisis. Detailed dietary and health surveys have been made in numerous countries in tropical Africa, Latin America, the Caribbean and other regions of the world. Many medical experts believe the situation is even more grave than these studies indicate, since victims of undernourishment who are already thoroughly sick, or dead, are seldom taken into account. For each case of malnutrition treated in the hospitals, many others never come under care. It is clear that the nutritional crisis has far greater dimensions than have so far been mapped out.

Vitamin-A deficiency frequently results in blindness, curtailing productivity. In India alone there are at least one million cases of such blindness. In East Pakistan 50,000 children every year are threatened with a possible lifetime of blindness due to their precariously low vitamin-A intake. The blind have limited opportunities to contribute to society and often become a drain on it. Yet, for a few pennies a year, such blindness could easily be prevented.

Deficiency diseases are extremely insidious in that they often sap vitality without causing other easily noticed symptoms; they thus frequently belong to the category of "hidden hunger." Hundreds of millions of people are now short of proteins, minerals and vitamins—not to the degree of manifesting precise symptoms but short enough to suffer from lowered efficiency, alertness, endurance and creativity.

One of the most significant findings of modern nutritional research is that protein hunger may cause devastating brain damage in infants. Since the damage is irreversible, it can lead to a lifetime of mental retardation or to other mental and physical aberrations. Similar effects are traceable to prenatal malnutrition. These findings should be a cause for overwhelming global concern. The recognition that malnourished children may emerge from childhood without the ability to reach their full intellectual potential injects a new and frightening element into development theorizing.

The implications are ominous. For many years we have assumed that, given educational oppportunities and environmental advantages, even children born to poverty have every prospect of growing up to be bright and productive. It is now suggested that malnourished children may become permanently retarded. The significance of this can be appreciated when we recognize that as many as two-thirds of the children of most developing countries are now suffering from some degree of malnutrition.

Much earlier it became evident that malnutrition profoundly retards physical growth—and this, too, in a frequently nonreversible way. In many developing countries the average twelve-year-old has the physical stature of an eight-year-old in Western Europe and North America. Indian nutritionists report that four out of every five pre-school children in certain areas suffer from malnutrition causing dwarfism. During the months of breast feeding, children from the poorest areas grow at a rate comparable to the best nourished children elsewhere. Usually, after six months of age, when breast milk is no longer a sufficient source of protein, growth is progressively retarded.

The relationship of malnutrition to mental growth dramatizes the issue, but the insidious drain of malnutrition on natural development takes other even more harsh forms. Half the deaths in the developing countries occur among children under six years of age. In parts of Southeast Asia, 40 per cent of the children die of disease in their first four years. This is a proportion of deaths not cumulatively reached in the Western world until the age of 60.

Most of these childhood deaths are commonly attributed to infectious diseases. Yet such diseases would be of relatively minor consequence in the West. Among children in poor countries, we now know, the cause of death is often not the infection alone but a combination of the infection and malnutrition. In other words, malnutrition debilitates the body to such a degree that it is incapable of resisting what otherwise would be a passing infection. In a country like Ecuador, child deaths ostensibly due to measles are more than 300 times more frequent (per thousand of population per year) than in North America. Whooping cough is still a major killer in much of the world. Similarly, chicken pox is often fatal because of poor nutrition. Diarrheas cause more deaths than any other infectious diseases through the operation of a vicious spiral: the diarrhea is keenly aggravated or even invited by malnutrition, and the malnutrition is exacerbated by diarrhea.

The world has close to one billion children below the age of 14. A very large number of these children will never reach adulthood. They will die prematurely, largely because of malnutrition. This is the tragedy of hunger in its grimmest perspective. To hundreds of millions of children life is very little more than a vigil of death; it is certainly no banquet.

A young girl in Nepal sits in her doorway.

The true economic costs to the poor world of nutritionally induced disease, inefficiency and death have never been calculated. They must run into many billions of dollars per year. Yet one can still encounter innumerable experts who would give health and dietary measures a very low priority in development programs. We face a gigantic educational task right in our own midst, thanks to a series of false notions and to the fact that most of our technology and much of our agriculture and medicine have lost sight of the ecological dimension.

The bulldozer and the miracle drugs may be chosen as symbols of Western man's simplistic faith that he has become the master of his destiny. Only gradually and painfully is he learning that he cannot go on working against nature if he is to endure.

The groundnut fiasco in Tanzania, the collapse of Gambia's big poultry project, the persistent spread of schistosomiasis in China, Egypt and tropical Africa, the resurgence of rodents in Europe and malaria in Southeast Asia, the firm hold of malaria and sleeping sickness in tropical Africa—all are examples of man's ecological malfeasance.

But far more serious is another shortcoming. We of the rich, well-fed world are subject to a gigantic self-deception. There is, for instance, nothing wrong with our impressive dairy development, but we conveniently fail to realize that its high level of performance depends on the influx from the hungry world of millions of tons of proteins, partly of high quality. And so with other aspects of Western food production. Europe, for instance, receives through the back door over ten million tons of feed protein and close to one million tons of fish protein. In the postwar period there has been a massive exploitation of the oceans, but only to a very limited extent does its bounty reach the poor. Japan and the Soviet Union have expanded their large-scale catching operations into all oceans—primarily to procure food to fill their own needs. They have been followed in high-sea fishing by Eastern and Western Europe. It is true that the most spectacular gains in ocean fishing have been made by a poor country, Peru. The result, however, has been to create a majestic feeding bastion not for Peru or Latin America but for the wealthy world, to which are annually delivered more than one million tons of fishmeal. Postwar developments have therefore seen a steadily growing percentage of ocean catches being earmarked to feed the chickens and hogs of the United States and Europe and to provide cheap margarine for the industrialized populations of Western Europe. The underfed millions remain . . . underfed.

One-third of the world, in short, is disposing of two-thirds of the harvests both from the lands and the seas. The West's glib talk of a Green Revolution therefore has implications quite different from those its propagandists like to talk about.

BACK TO REALITY

Facing the world food issue, it is high time we abandoned simplistic notions and came to grips with the complexities. Despite innumerable projects and an almost hypertrophic bureaucracy within WHO (World Health Organization), FAO (Food and Agriculture Organization), UNESCO (United Nations Economic, Scientific and Cultural Organization) and other specialized agencies, the joint efforts of governmental and international organizations have yet to reflect the magnitude of this issue. There is little awareness that, to avert catastrophe, mankind must mobilize all its available resources in money, material and brainpower.

The most serious fallacy connected with the world food issue is the idea that man's globe is limitless, when it should be evident to everyone that our planet is clearly restricted in its resources of soils and water. Over the centuries, biologically useful forests and pastures have lost far too much ground to the plow; this implement has been pushed by mankind's growing millions into places where it has no business. Despite ingenious irrigation accomplishments, it has helped man convert far larger acreage into deserts than he has managed to transform into productive farmlands.

The self-destructive process continues. One-third of the irrigation water of the Nile is already used to remove salt left largely by previous irrigation. Man is fighting a desperate struggle with salt, and he has rarely managed to turn this battle from a losing to a winning one. Soil erosion is furthermore taking a frightful toll. In critical areas where land should be reverted to forests and grasslands or where grazing pressures should at least be reduced—all with the urgent aim of saving the topsoil—the old hell-for-broke exploitation continues. We here touch upon the basic ecological requirements for life.

Instead of protecting our land at high productivity for future generations, we have contended ourselves with busy-work. Much of this busy-work reflects an almost religious faith in gadgets. We naively seem to assume that by willing the means we attain the goals. If someone in a fire station got the idea that silencing the alarm clock would be a good way of handling fires, we would classify him as a mental case. Yet this is the way we act as a human family in facing malnutrition.

We talk about giving the world adequate amounts of fertilizer, forgetting to analyze water as the major limiting factor. Only one-tenth of all fertilizer is currently used by the hungry world and, absurdly enough, not for food but for cash crops. Many times more fertilizer is needed for adequate harvests today and still more to feed the additional billions of people we will have at the end of the century. But is there water enough to accommodate such a massive chemical assault on the soils? Presumably not.

Today we talk about high-yielding strains of wheat and rice, forgetting that their productive capabilities have to be honored with much more water, much more fertilizer, more insecticides and fungicides, greatly expanded storage and processing facilities, and vastly increased amounts of capital. Even assuming all this is possible, we have yet to face up to the ecological consequences. Only in very few instances do we know if these new strains will stand up in entirely new environments and under bombardment from insects and fungi to which they are not adapted. Simply by hoping for the best, we will not attain our goals. What is required is a sophisticated strategy and large-scale measures.

GLOBAL INSANITY

Despite the euphoria over various new high-protein foods now emerging from laboratories—spun soybean protein, fish and grain protein concentrates, and so forth—their impact on human nutrition has been insignificant. There is no sign that they will be distributed to the hungry on a massive scale in the foreseeable future. Meanwhile, as the talk goes on and as the gap between words and action grows and grows, the ranks of the hungry increase by millions each year. It is not sufficient, in this crisis, to provide free or low-cost school lunches, to cure infants suffering from kwashiorkor, to help an occasional Indian village, to ship food relief to Colombian "campesinos" or Polynesian islanders, and to set up soup kitchens in the slums of Lima and Sao Paolo. These are all commendable acts, but the world has long ago passed the point where charity sufficed.

In conclusion, I would argue that the hunger crisis reflects man's inability to imagine what he already knows. We are participating in a grand-scale evasion of reality which bears all the signs of insanity. In order to bring health and restore vitality to the whole human species, nothing less is required than a global will to act, simple justice, true population control, worldwide food planning, effective execution by the scientists, engineers and public leaders of states and regions—and a massive commitment of funds. Furthermore, the resources of lands and seas must reach the larders of all mankind, not just the wealthy. It is time the West kept faith with the Atlantic Charter, which proclaims that all peoples should have equal access to the harvests of the world.

Communications

OCEAN SCIENCE

The February 1970 issue of the **Bulletin** carried a cover photograph and cover head: "Marine Science and Ocean Politics." The issue itself contained two articles, "Marine Science and Ocean Politics," and " 'Tektite': A Blueprint for Cooperative Undersea Scientific Programs," concerned with this subject matter.

By way of comment I would like to quote in their entirety several paragraphs from "Effective Use Of The Sea," report of the Panel on Oceanography of the President's Science Advisory Committee, June 1966:

> The most urgent aspect of Federal involvement in ocean science and technology for the next 5 to 10 years relates to national security in the narrow, strictly military sense. The U.S. Navy, which has responsibility for essentially all our defense efforts involving the ocean environment, will have increasing need for specialized oceanographic data for specific devices being developed or improved and will continue to require better understanding of characteristics of the ocean environment in which it operates.
>
> The effectiveness of the submarine-based missile force is highly contingent on concealment, dispersion, high mobility, and very long patrol time. It is precisely for this reason that key interests of oceanography and the Navy, reflected in the development of the submarine-based strategic-missile force, have so much in common. With this relationship in mind the Navy instituted a special program of long-range research support for academic oceanography and intensified field studies by its own laboratories and ships. Even so, oceanographic research needs continuous and vigorous support from the Navy. This research must cover on a massive scale the entire technological spectrum from basic and applied research to marine engineering. For example we must be able to verify that no presently unkown (to us) physical effects in the ocean environment make nuclear submarines susceptible to continuous tracking and location. Because of the possible increased emphasis in our strategic-defense capabilities in terms of the Navy's submarine-based missiles, and because this emphasis would only be well placed in the absence of any degradation of the submarines or of the enhancement of detection capability, the Navy must support a program which continuously explores all aspects of the ocean environment which conceivably could be exploited or utilized to allow continuous targeting of such submarines.
>
> In summary it is very possible that the kind of strategic offensive force we may wish to develop for the future will rely even more heavily on ocean-based systems than that which we now have. Such systems may very well require operations at a much wider range of ocean environment and for much longer times than at present. Thus, the need for oceanographic research and support of these weapon systems becomes even greater and will certainly have to encompass a wider problem area in development and maintenance of present submarine forces.
>
> These problems will range from ascertaining that the ocean-based systems cannot easily be compromised by an enemy's exploitation of some hitherto hidden effects of the oceans's environment to development of massive ocean engineering capabilities. It is likely that the Navy's involvement in oceanographic research to develop, support, and maintain our weapon systems will increase rather than decrease in the future and will include a more widespread range of problems than it currently does.

It is unfortunate that this context is nowhere found to be explained in the February 1970 issue of the Bulletin, and is alluded to only in a single sentence of Dr. Cheever's paper: "All are aware that the continental shelf, the slope, the deep-ocean abyss and, most particularly, the mid-ocean ridges and sea-mounts have military value."

As this context alone is responsible for the burgeoning funds which have in recent years become available for oceanography, and the resultant expansion of knowledge in the area, it deserves more ample treatment than a single sentence, both in its general aspects and in regard to particular developments, devices, and research. Journals concerned with military and nonmilitary development of the oceans are much more explicit on this matter. I cite a few examples:

1. G. B. Anderson, "A Path to Explore the Oceans," in "Astronautics and Aeronautics," April 1969:

> The motives which, taken collectively, help explain the drive into oceans might be summarized as follows: First, national defense. Our navy must be provided the capability to exercise dominant control over the total ocean volume of strategic interest to this country. . . .

2. C. F. Duchein, "A Control-of-the-Sea Concept of Oceanic Research" in "Navy Magazine," July 1968:

> As Dr. Athelstan F. Spilhaus, father of the Sea Grant concept observes: 'To do it better than anyone else, we must be able to move faster in the sea, to go deeper, stay down longer, to exploit more with resources, and to have more power, whether it be fire power to protect or power for maritime industries. And, above all, we must understand more about the sea than anyone else—its interface—and interaction of the atmosphere—its bottom—its shorelines—the motions within its bulk—and about everything it contains—the life and chemicals in it—the challenge is to be superior in all of these aspects of oceanic research to our competitors. . . . Control of the seas is the crux of the competition with the Soviet Union and its burgeoning maritime power.

3. R. J. Alexander, "Oceanography and Future Naval Warfare" in "U.S. Naval Institute Proceedings," June 1963:

> A general review of our naval weapon arsenal will show that every major weapon system or operating technique developed since 1952 has required extensive oceanographic data in the development state.

Journals such as "Naval Research Reviews" and the "U.S. Naval Institute Proceedings" have had literally dozens of articles explicating the relationships between oceanographic science and strategic military requirements. The article titles are direct and to the point, such as "From Science, Sea Power," "Oceanography and Naval Warfare." In discussing prospective oceanographic funding a year or so ago, an editorial in "Undersea Technology" paraphrased Louis XIV's "Apres moi, le deluge" with an editorial caption in inch-high type: "After Vietnam, the Oceans." The urgings have not been far off. The calls for "a wet NASA" are numerous. This would be a deluge in fact.

If one looks at Tektite in particular, the considerations are not far removed from the general ones. Though the project has not had the magnitude of obfuscation that has accompanied the Sealab program, the efforts to confuse that have been devoted to it differ only in degree. Sealab at least was rarely projected as a program with civil intent or application, though in the enormous ballyhoo that accompanied it, it was never quite stated what it was for. Sealab's mission, projects and function were defined by the U.S. Navy Mine Defense Laboratory which has obligations far beyond mine defense. Project supervision and utilization of Tektites and other Habitat projects are a bit more decentralized, but Navy interest is in the test-bed function of Tektite for human engineering and other behavioral, logistical and personnel aspects in regard to the one-atmosphere undersea stations which are being developed for implantation at much deeper depths, such as 1,000 and 6,000 feet, under purely military supervision. Tektite was also built by G.E.'s Missile and Space Division, a major contractor on these naval projects.

There was no discussion in the February 1970 **Bulletin** of the relation of the matters written about in its two articles on oceanographic topics to one of the major arms control treaties now under discussion in Geneva. This is a minor lapse. The major lapse is much more serious and a grievous danger to the journal. That is a euphemistic disregard of the relevance of the strategic military aspects of the essence and core of a scientific problem, situation, or issue. A recent issue of "Scientific American" was devoted entirely to the oceans, and again the contexts described by the above material were supplied by only a single sentence, in an introductory paper, and by more oblique phraseology than that used by Dr. Cheever. But the issue is far more critical to the **Bulletin** because of the very nature of this journal. If there are civil utilities to oceanographic research are they represented in present programs? If so, in what proportion? What are the directions, interests and functions of present research, its administration and projects? Is the effort again to be pleaded or apologized for on the basis of "spinoff"? Are military aspects to be glossed over — or never mentioned in public? The **Bulletin** exists to join such issues and to lay them out explicitly. Science must not be a baited hook to drag even this very journal into the depths of the sea.

MILTON LEITENBERG

Stockholm International Peace Research Institute

NATIONAL LABORATORIES

In the February issue of the **Bulletin**, in my article entitled "Reflections on National Laboratories," I wrote that at the present the only full-fledged graduate school in the sciences connected with a national laboratory was a small school in applied physics at the Lawrence Radiation Laboratory. As it turns out, there is in fact another example for such an organization: The Oak Ridge Graduate School of Biomedical Sciences. Its director, Dr. R. C. Fuller, was kind enough to call my attention to this school and send me information on it. It began operating in the fall of 1967, and turned out its first PhD in the fall of 1969. Besides its director, it has three full time faculty members and some 65 "shared" faculty members, drawn from the staff of the biology division of Oak Ridge National Laboratory. It has, at the moment, 25 full time PhD students and expects quite a few additions next year.

I am very glad indeed to be corrected on this count, and I hope that this school, as well as the applied physics school at Lawrence Radiation Laboratory, will receive more publicity, including a careful appraisal by directors of other national laboratories so that more such schools can be established, if it is found that they have been successful.

MICHAEL J. MORAVCSIK

University of Oregon
Eugene, Oregon

TEKTITE

The discussion of the Tektite program in your February 1970 issue includes a presentation that might be considered slightly misleading. . . .

At the conclusion of the excellent summation of what the Tektite I and II programs entail, authors Edward Ray and Robert Cohen state: "The Department of the Interior intends to play a major role in this regard by exploring and developing the Nation's marine resources so that these new markets will be economically viable."

Just prior to this advocacy of the Interior Department, there is reference to the report of the "President's Commission on Marine Science and Engineering" (actually Commission on Marine Science, Engineering and Resources) without any hint of the report's major conclusion.

The two-year study of the Commission, headed by Dr. Julius Stratton, former president of MIT, concluded that it was essential for the national ocean program (and for development of ocean markets) to establish an independent national oceanic and atmospheric agency. Implicit in this recommendation is rejection of the Department of the Interior as a suitable home for civilian oceanography programs.

This judgment has been endorsed by most qualified observers in public testimony on legislation creating such an agency. The fact that the General Electric Company is working closely with the Interior Department on a project should not lead anyone to think the implied endorsement by GE of the Interior Department's effort to acquire control of oceanography is representative thinking.

RICHARD N. RIGBY, JR.

Executive Director
National Oceanography Association
Washington, D.C. 20036

ANN E. BERTHOFF

Mumbling and Fumbling — or Lying?

Bruce M. Russett contends that one of the costs of the Vietnam war may well be the "erosion of some past efforts to establish principles of restraint on the conduct of aerial warfare" (**Bulletin**, January 1970). Vietnam, he concludes, has been a setback to our credibility as a nation committed to a doctrine of restraints against incurring civilian casualties, a development we may have cause to regret.

In Russett's view, our failure has been twofold. First, we have not made clear our reasoned compromise between counter-force and counter-value strategies in the bombing of the North; that phase of the war was waged under restraints, but fear of hawkish criticism inhibited Secretary McNamara from clarifying them. Second, the conditions of war have made it impossible to distinguish "the enemy" from "the general population." Thus "an opportunity to provide a clear example of avoiding civilian targets was fumbled." Russett's description of the effects of our failure is incontestable: "On the whole the avoidance of civilian casualties probably did not appear from the other side as a primary American goal."

The view offered, that we have humane intentions which have been obscured by unlucky public relations and foiled by the exigencies of guerrilla warfare is a familiar feature of the arguments of apologists for the war, as is the very contention that we have waged war under restraints — the notion of a shackled Goliath, in Professor Robert Scalopino's phrase. And it is a view consonant with Russett's opening remark, that the Vietnam war is "a tragic mistake." The tragedy of Vietnam, however, is not that it is a "mistake" but that it has been planned and plotted and waged according to plan and plot. The tragedy of Vietnam is not that we have mumbled or fumbled but that we have deluded ourselves with such explanations. There has been no such opportunity for exemplary action as Russett describes, because the logic of our strategy precludes it and precludes it absolutely.

NO RESTRAINTS

Our policy in Vietnam has involved us in a series of self-defeating actions — "We had to destroy the town in order to save it" is the best-known formulation — each of which manifests the absurdity of fighting a civil insurgency with the weaponry and tactics of all-but-total war. The devastating effects of this desperate war may have been rationalized by appeals to military necessity, but it is a logical necessity that restraints cannot be exercised in an air war against guerrillas. Indeed, the "erosion" began with the initial decision to employ massive air power. It is fatuous to claim that we have intended restraints which have been impossible to observe, given the conditions of war in the south, or "given the bombing of the North at all." If the conditions make observation of restraints impossible of fulfullment, then the claim of intending to act by a doctrine of restraints is meaningless. The contract, as it were, is void from the beginning.

Nowhere in his curiously bland account of the air war does Russett consider the possibility that the implementation of U. S. policy is coextensive with a very high rate of civilian casualties, or that civilian casualties — estimated as early as 1966 as being at the rate of 10 to one military casualty — are therefore part of a cost which has been deliberately calculated and judged necessary to policy goals. To cite only one example, the designation of free-fire zones (now called "specified strike zones," areas in which targets may be attacked on the initiative of U.S.-Free World commanders) is a tactic which has killed thousands and has generated refugees by the hundreds of thousands. Russett nowhere entertains the dread possibility that virtually unrestrained aerial warfare has been undertaken with deliberate intent; that the effects of the air war have been the calculated aim of our strategists; that the United States has chosen willfully to destroy the fabric of Vietnamese society and to destroy the earth itself in order to deny to the NLF control of population or ground. As it was put by a U.S. Army officer in the field: "If the people are to the guerrillas as the oceans are to the fish, then . . . we are going to dry up that ocean."

LYING LANGUAGE

Of course we tell ourselves it is not so: a burned hut is an "enemy structure"; a dead Vietnamese is a "VC." This lying language, however, is not the result of biased field reports or of inaccurate body counts. It is the camouflage devised for a policy which does not seek to define the civilian population as other than the enemy — except, of course, in the rhetoric of our supposed intentions. We can say we are in Vietnam "to assure the self determination of the South Vietnamese people"; we are there "to win the hearts and minds of the South Vietnamese people," to provide "a shield behind which the people of South Vietnam can work out their own destiny," etc. Who, then, are those we napalm and bombard? When we get to individual cases, "the South Vietnamese people" become the "infra-structure," the inhabitants of a "suspect hamlet," "VC sympathizers," "out and out Communists" or "North Vietnamese Regulars," people who "unfortunately got in the way while a war was going on" — victims of military necessity.

It is to protect ourselves from the logical requirements of our primary strategy that we have developed a lying language and a fraudulent logic by which to describe its purposes and consequences. Thus we have depended on the declarations of our good intentions, whether loud and clear or mumbled and ambiguous, to exonerate ourselves. They have not always, in my opinion, been declared in bad faith, but good intentions about good intentions do not gainsay the fact that rhetoric has been called in to do the work of policy.

Although he notes the discrepancy between our professed intentions and the actual effects of our strategy, Russett is not concerned with the crucial relationship of saying and intending nor with the problem of differentiating contingencies from necessities. Political science — Russett's field of expertise — addresses itself, surely, to the grammar and rhetoric of motives, to the relationship between what we say we want to do and what our policies require that we do. This political scientist, however, seems to accept the rationalizations of the strategists whose strategies he seeks to analyze. That analysis is that we have mumbled and fumbled. Russett has no ax to grind and he is not self-righteous; he is, simply, superficial. The tragedy of Vietnam is not that America's image has been blurred but that she has destroyed her good name.

When the logical contradictions of our policy and its actual effects are forthrightly confronted, the conclusion must surely be other than Russett has presented at this late date. Language more appropriate to the moral disaster of the Vietnam war will also be more appropriate to its significance in an historical and strategic sense. I cite as an example Senator Proxmire's comment with reference to the level of bombing in 1968, that it is "the military equivalent of nuclear weapons, and to the South Vietnamese . . . it is the moral equivalent of nuclear war" (Cong. Rec., June 25, 1968).

GET OUT OF SOUTHEAST ASIA
S. Harris

"That's very un-Pentagon, Willis."

SHOOT THE MESSENGER

The self-evident failure of a policy which leads us to destroy what we would preserve has resulted not in re-examination of assumptions but in changes in the language of apologetics. Just so, analysis of the true shape and intent of American policy has been met with distaste, horror (at the treachery involved in making such unpatriotic disclosures), and disbelief. Over and over again, the messenger with the bad news has been shot. Most radical critics of the war — those who do not believe that Vietnam is a "mistake" — probably lose hope intermittently that exposure of fraudulent claims and the demonstration of the logical contradictions of our policy will lead to an actual change of goals. ("Vietnamization" is, of course, only a verbal trick.) But that effort to define must nevertheless continue.

We Americans may, some day, have cause to regret that our image as a nation committed to a doctrine of restraints against incurring civilian casualties has been dimmed. Russett implies that punishment may await us. But his tentative prophecy — unaccompanied by any statement of the fundamental incompatibility, in a guerrilla war, of restraints and the use of massive airpower or by any sign of recognition of the dimension of criminality in American prosecution of the war in Vietnam — is as impertinent as those belated criticisms of the war on the grounds, simply, that its cost in "blood and treasure" has become too great a burden for "our people."

Although the assessment and assumption of the moral cost of Vietnam will be the work of generations, it must begin now. It will be delayed for as long as Americans fail to examine the assumptions whose nature and consequences we have hidden from ourselves by a lying language. The tragedy of Vietnam is that we have come to believe our own lies.

Ann Berthoff, associate professor in Department of English at the University of Massachusetts, Boston, has served on the National Policy Committee of the Women's International League for Peace and Freedom and is currently associated with the Concord Area Committee for Peace.

KILLING OF ONE'S OWN SPECIES

(Continued from page 5)

that hurts the species, not to mention killing members of the species. We shall also see under what circumstances these control mechanisms fail.

Again we turn to the cichlids. We have seen that it is necessary for the preservation of their species to be very aggressive, since under natural conditions the breeding pair is attacked literally every few minutes by an expansionist neighbor. The circumstances under which inhibitions fail to keep a couple from fighting each other are of great theoretical interest. It was these malfunctions that led my late friend Bernhard Hellmann and myself, more than 30 years ago, to the discovery of certain properties — not only of aggressive behavior, but of instinctual behavior in general. If an organism is kept from experiencing a normal stimulus for any length of time, the inner preparedness for the specific response to it will increase, and in marginal cases result in the whole behavior pattern being performed "in vacuo." The response will erupt without the stimulus ever occurring. This process is described as lowering the threshold of releasing stimuli. This threshold seems to be the best means of measuring the accumulation of readiness to act, the physiological nature of which we are still far from understanding.

The observations we made — the interpretation of which still keeps ethologists busy — were simply these. If several pairs of cichlids are kept in one big aquarium, all kinds of harmless border disputes will occur, but never serious casualities. Above all, there is blissful peace between all husbands and wives. But if one cichlid pair is put into an aquarium all by itself, in the hope that it will facilitate their breeding, most cichlids, after a certain amount of time that varies for different species, will become involved in a true tragedy. Quite suddenly husband and wife will begin to fight, and unless the experimenter intervenes the stronger one, most of the time therefore the male, will simply kill the weaker one, the female. It is then quite difficult to find another partner for the surviving husband because he is likely to react to the new partner aggressively instead of sexually, and this aggressiveness will be the more intense the longer he has been alone in his aquarium. It was Hellmann who, already at that time, had sufficient intuitive insight into these behavioral disturbances to devise a method for overcoming these difficulties. He simply put a mirror into the aquarium and thereby gave the cichlid the opportunity of acting out his pent-up eagerness to fight. Once he had fought sufficiently against his mirror image, he was again able to react sexually to the female that was then put into the aquarium.

ACTING OUT

Comparable disturbances that were the consequences of insufficient opportunities for acting out normal and species-preserving aggression can be found in many other animals, and it is probably not too daring to assume that they also occur in the human species. We all know that humans, deprived of their normal ability to act out their "justified annoyance," exhibit similar lowering of their stimulus threshold for aggressive behavior. Anyone who has had the experience of spending an extended time either on a long expedition or in a prisoner-of-war camp, where one goes to extremes to avoid conflict and blow-ups, will have been able to observe this strange behavior in himself. Under the circumstances, one is likely to react aggressively to the slightest provocation, to the most harmless remark by a dear and highly esteemed friend. We may react to the way our friend blows his nose as we normally would only to a most severe offense by a deeply hated enemy. The worst of it is that in such a situation insight into the reasons for this anomalous behavior is of no help. Even if we should be able to control our outward behavior, the fact will remain that our dearest friend is wearing terribly on our nerves.

It would seem that civilized man lives under circumstances that do not give him sufficient opportunity to act out his aggressive instincts. I should like to see the psychologists, and especially the depth-psychologists and the psychoanalysts, turn their attention to this phenomenon. Genetically speaking, instinctual behavior is even more deeply rooted than morphological characteristics, and the amount of aggression we accumulate is probably not much below the level of our warring early ancestors. It is more than probable that the evil effects of human aggression, which Sigmund Freud explained by assuming a special death instinct, is simply a result of the fact that the intraspecific selection of humans in grey antiquity has bred into us a measure of aggression for which today's society finds no adequate outlet.

To find a solution for our fish was easy; we simply provided them with artificial outlets. We bred the aggressive cichlids by keeping two pairs in a large aquarium, separated by a glass pane that allowed them to see each other all the time and gave them ample opportunity to annoy each other. It was important to keep these panes very clean. If their transparency was even slightly reduced, for instance through some growing algae, the acting out of aggression could become sufficiently impeded so as to bring about the marital tragedy we described. It might sound like a joke, but often it was the incipient conflict between husband and wife that drew my attention to the fact that the separating glass panes were overgrown with algae.

PRIMAL BATTLE

These behavior disturbances which under certain circumstances lead to death are not the only contribution the study of cichlids can make to understanding the problems of our day. Phylogenetically, comparative analysis of the fight between two rival fish of the same sex permits us to see a very interesting behavior-physiological mechanism. This mechanism directs aggression into channels

Cichlasoma Biocellatum — Breeding pair with young.

which, while giving full scope to the species-preserving functions of aggression, at the same time reliably prevent any injury or death of the species member. The primal form of battle among bonefish consists of opening the mouth widely so that the teeth of the far-advanced jaw protrude, and so armed, each fish tries to ram the other's side. This is the first form of fighting which recurs in the ontogenesis of most bonefish. There are, however, very few fish, in which the adult possesses exclusively the one, immediately damaging pattern of fighting behavior. This mouth-to-mouth fighting is characteristic of American sunfish, as well as of some other perch-like fishes which are closely related to the Cichlidae. In some of the latter, in those in which the fighting patterns are least highly developed, as in Haplochromis and other mouthbreeders, mouth-fighting is only the last preamble to the "serious" damaging fight in which the antagonists ram each other's flanks. And it is this damaging fight that determines the winner.

In most cichlids, however, this mouth-to-mouth ramming has been differentiated to form a quite particular motor pattern of fighting, in which the rivals either push their jaws against each other, as in the genus Tilapia, or else lock jaws in a firm grasp and pull with all their strength. This is the most widely distributed form of fighting in the family of Cichlidae. The ultimate damaging fight has become very rare indeed among them. In some species, it seems never to occur at all, unless a pair of adversaries are selected whose strength is perfectly matched; otherwise one of the combatants throws in the towel after a shorter or longer mouth-fighting contest.

The overwhelming majority of bonefish begin fighting with the so-called threatening-impressing ceremony in which the fish simply spreads all vertical fins, including the gills, and offers to his opponent his broadside so that he appears to him in his largest possible dimension. The species-preserving achievement of that movement is easily explained: it allows the inferior opponent to be intimidated and to flee before he can be seriously injured in a hopeless battle. For most bonefish the optical threat is supplemented by a second maneuver which allows tactile proof of superiority. The fish, in parallel position, spreads out its tail fin, hitting sideways with all its might, so that a strong water wave will hit the other fish's lateral line, an area particularly sensitive to pressure. For some species of fish this form of threat is immediately followed by the damaging ramming thrust. But with labyrinth fish and some other species there intervenes still another threatening pose, this time frontal, the last threat before the actual attack. Even in these species the attack does not begin with the movement that inflicts severe injury, but consists of ramming movements aimed at and repulsed by the opponent's mouth. Some fish simply push against each other; others grasp each other's jaws and then pull with all their strength. During this fight, the weaker one in due time will give up and retreat.

The fact that the rival is practically never rammed in these fish is not due to the absence of the motor pattern of ramming in the species concerned, but to specific inhibitory mechanisms which act under equally specific circumstances. It is only the fellow member of the same species which is treated with "fairness," and only as long as he keeps to the "Queensberry rules" and retaliates by the species-specific motor patterns described above. If he gives up and flees, he is pursued with an entirely uninhibited ramming thrust, just as any nonconspecific enemy, for instance a large predator, is attacked. The only way to evoke the truly dangerous fighting is to select most carefully a pair of fish whose strength is perfectly matched.

All this does not mean that the cichlids have lost their ability to fight; rather there is an inhibiting mechanism that controls it. Toward a more serious enemy, such as a large predatory fish, these same cichlids immediately mount their ferocious ramming attack without any preliminary threatening gestures.

MATING MOVEMENT

The inhibition against seriously injuring the opponent operates only toward members of the species, and only as long as that member follows precisely the dueling rules. Under those circumstances, the inhibition can be fully relied upon, more than any other — even that evoked through sexual attraction. The mating movements of sexual partners do indeed tame the aggression of the male fish considerably; nevertheless, the female mate is more likely to receive a good hard push once in a while than is the "fair-fighting" weaker rival fish. The species-preserving function of these fights is beyond doubt. Especially for the cichlid, the selection premium on aggressive behavior is high: without it they could not defend their progeny. If several couples are kept in one big aquarium, it quickly becomes evident that the big fighting males bring up more offspring than the weak small ones. At the same time the cichlids are a relatively small species, constantly surrounded by countless bigger predatory fish. Thus it is easy to see how important it is for the species that the fish, who has just been conquered in an intraspecific duel, can survive to take the place of his conqueror, if that unlucky victor should later be eaten by an egret.

Strictly ritualized fighting of this sort is found in innumerable other vertebrates and even in some invertebrates. It exists, at various stages of development, among other bonefish, reptiles, birds and mammals. Significantly enough, it reaches its most differentiated form — that is, it deviates most from its original injurious purpose — among those animals for which a serious duel would be particularly harmful to the preservation of the species. For instance, certain poisonous snakes cannot afford to bite their rival, not because the rival would die from the poison, but because the snake would injure its highly specialized poison apparatus. Male vipers engage in strange wrestling bouts which lead to complete exhaustion and eventual surrender by one of the combatants. In these bouts the fighters envelop each other with the lower one-third of their bodies, place the fronts of their bodies tightly against each other and, thus, holding themselves erect they press with their heads against each other. In that position they inflate their lungs, which eventually causes them to lose their hold on each other and to fall hard to the ground or against the stones, like springs that suddenly uncoil. Interestingly enough, neither hurts the other but only himself. It is through these self-inflicted injuries that one of them finally, in exhaustion, gives up the fight.

Another peculiar duel is fought by the famous marine iguana of the Galapagos islands. Here the males limit themselves to pushing with their foreheads against each other in the manner of stags or bulls. In remarkable convergence, again like stags and bulls, their foreheads are armed with horn-like excrescences. Here, the genetic necessity to avoid a damaging fight probably stems from the danger of their razor-sharp jaws. These were evolved to cut down the hard ocean plants on which this reptile feeds, and would inflict deadly injuries.

GENOCIDE PREVENTION

We have thus touched on a problem of considerable importance, namely, on the relationship between the effectiveness of the armature of a species and the inhibitions needed to prevent killing members of the species. A raven could with one blow of his giant beak blind an eye of his opponent; worse, he could kill his opponent with one blow. The species would perish were it not for a very specific inhibiting mechanism that prevents such happenings. The raven never aims at the eye of another raven, not even in the angriest fight. Yet he seems to aim precisely at the eye when he is about to kill a prey. Since this inhibiting mechanism functions also vis-a-vis humans, if the raven is tame, Heinroth and I were able to observe this behavior closely. The raven avoids, with great diligence, contact between its beak and the eye of a friend, even if one makes an effort to bring one's eye up close to the point of its beak. Its reaction will be to turn the beak to the other side with some guarded movement. In contrast, if one approaches the raven's face with one's hand, it will repel the hand with a tender but intensifying pecking of its beak against the hand. It was amusing to see how the raven treated Heinroth's glasses: as long as they were on the nose, they were treated as eyes. The minute they were removed, the bird tried to get hold of them and hide them in some inaccessible place. Only in one very special situation did the raven allow his beak to come close to the eye of a member of his species or to a human friend. This was in the course of what we call social grooming. Like many animals, such as monkeys and parrots, ravens clean those parts of each other's body which they cannot reach themselves. That is, first of all, the head and the parts around the eyes. A raven will carefully and patiently preen with his beak the feathers that surround the eye of another raven. And a tame raven will do this without difficulty for the eyelashes of his human friend. To an outsider this looks simply blood-curdling and one is therefore likely to receive a serious warning from a witness to this demonstration. In such a situation, I have said that I fear the raven less than my well-meaning friend, because I know of cases of an undiagnosed paranoid killing his friend, and I considered the danger of such an undiagnosed paranoia greater than the possibility that the inhibition mechanism of the raven will fail.

The injury-inhibiting mechanism is also related to the thickness of the animal's skin and to the resistance power of the skin at various parts of the body. If one plays with tame mammals, one learns quickly that those who have the thickest skins, without any cruel intent, act most roughly. With the relatively thin-skinned or tender-skinned dogs and cats, one can engage in battle plays of various sorts without risking any serious injury. But the thick-skinned badger, in all friendship, bites so vigorously that a human playmate soon finds his skin broken. If one watches dogs or wolves play with each other, one can observe that they will not hesitate to bite strongly into the thick skin of the back of the neck, which is moreover protected by a mane; but they will move their teeth most tenderly if they come to the throat.

Among the mechanisms that inhibit intraspecific killing, the so-called submission or appeasement gestures play a special role. These gestures are the opposite of the threatening gestures. Cichlids, when they threaten, spread all their fins and turn their broad side toward the opponent; in their submission posture, they hold all their fins close to the body and move into a position that will show the superior opponent the smallest possible outline. Laughing gulls turn their black face masks toward the opponent if they want to threaten, but turn their heads away if they ask for peace. And these examples can be multiplied indefinitely.

Some of the appeasement gestures have developed from the mating movements of the female, also designed to inhibit male aggression. Thus, among many baboons the exposure of the backside, originally the female gesture denoting readiness for copulation, has developed in both female and male into the general submission gesture that will immediately inhibit an attack. Interestingly enough, the reverse has happened to the cichlids: here the mating female gesture has developed from what was originally a nonsexual submission gesture.

It is a peculiar characteristic of some of these submission gestures that on the surface they seem to facilitate killing: the animal asking to be spared exposes to his opponent the very part of his body which, if injured, would allow the most dangerous wound. It would also be the very first target of his enemy in a real fight. Submissive jackdaws expose the backs of their heads to those that outrank them in the pecking order. Attack will then immediately change into socialized skin care, into the preening of the feathers on the back of the other bird's head. Among dogs the inhibiting effect is even clearer. I have repeatedly observed that in a fight when the losing dog assumes the submission gesture, the victor executes the throat-shaking movement, so to say, with disengaged clutch — that is, without real biting, merely holding his muzzle very close to the neck of his conquered opponent.

FRATRICIDE

I have described this animal behavior in such detail in order to show that intraspecific killing is prevented not by the gradual weakening of an originally strong aggressive instinct, but rather through various inhibiting mechanisms. These are, without doubt, located in the central nervous system, having developed under pressure of natural selection, very much like some special organ. I believe, from the observation of these mechanisms in animals, particularly of their limitations and failures, that there is much to be learned from them which is applicable to the present predicament of man. Like no other creature before, he is threatened by general fratricide.

INSTINCTUAL AGGRESSION

There can be little doubt about the instinctual nature of human aggression. But it is necessary to ask whether man has innate reactions that can inhibit his aggression in the interest of the preservation of the species. There is a widely held view that all behavior that does not directly serve one's self-interest must be the result of reasoned moral responsibility. This view is only partly correct. It is certain that our reasoned moral responsibility can make major contributions to the solution of our urgent problems. But it is equally certain that no such solution is likely to work unless it appeals also to man's nonrational emotions that keep him from killing.

The existence of this nonrational inhibiting mechanism becomes most clearly apparent in situations where our rational considerations could not possibly object to killing, namely, when we kill animals. Although some religions simply forbid the killing of any animal, it would seem that even the strictest self-questioning in canons of Kantian morals does not lead to the denial of such killing. Nevertheless, any normal human being finds in himself powerful emotional inhibitions that make it difficult, sometimes even impossible, for him to kill an animal. It is worth investigating the circumstances under which these inhibitions emerge because their original function indubitably was to prevent us from killing members of our own species.

Like many other such neurophysiological mechanisms, they can be elicited by simplified imitations of the biologically adequate stimulus situation — in other words, by "dummies." That our inhibition against killing higher animals is a by-product of our man-killing inhibition is borne out by the fact that the more an animal resembles man, the more difficult it becomes for us to kill it, even if these resemblances are purely external. Invertebrates usually do not evoke our killing inhibitions; among vertebrates we find fish the easiest to kill. Whoever has been forced to kill frogs (and possesses a measure of self-observation) will agree that it is the human-like arms and legs of these creatures that render their slaughtering so odious, though from the point of view of neural and "mental" development they are vastly inferior to the higher fish. To kill a mammal, even one of the lowest order, is very hard for me, and not for all the world could I kill a dog, let alone a monkey.

There is another circumstance that tends to confirm that these inhibitions derive from an innate mechanism that originally kept us from killing fellow humans. If young animals resemble a human baby in some way — for instance, by their thick head, their round forehead, their large eyes and round cheeks — our emotional inhibitions against killing that animal grow. When I once made a determined effort to overcome these "silly, bleeding-heart emotions" and did indeed kill some baby rats, I was punished for it by a regular little neurosis that manifested itself in painful dreams that would return regularly for weeks on end.

KNOWING THE VICTIM

It is now time to discuss in somewhat more detail the circumstances that will assist or hinder the effectiveness of this killing-inhibiting mechanism, quite independently of our reasoned moral responsibility. One condition that will invariably strengthen the mechanism is our being personally and individually acquainted with the potential victim. In zoological and physiological institutes, one can observe a recurring incident. Animals are bought to be sacrificed later for some research purpose. Then circumstances will postpone the event, and when the time comes around, the experimental animal has changed into a pet which nobody wants to kill. This is especially true for an animal that was brought in while rather sickly and then was nursed back to good health. It is almost touching to see how these serious men of science will lie to themselves and find some pseudo-rational reason for not killing, only to avoid the admission of strong emotions against the killing of that ordinary little animal. At very big institutes, where the experimental animals are merely anonymous mass merchandise, such reactions hardly ever occur.

All our inhibitions against killing are strengthened as our contact with the dying animal grows, and the connection between our actions and its suffering becomes more obvious. It is much easier to put a rabbit into a chloroform box than to strangle it with one's own hands. Cries of pain have a strong inhibiting effect, and I suspect there is a good deal of pseudo-rational lying involved when we persuade ourselves that a quick painless killing is permitted. What such reasoning accomplishes is to permit us to kill by keeping from us the cries of pain that might make us emotionally unable to fulfill our intent. Most people who today go hunting for pleasure would not continue their sport if the connection between the small finger movement and the wounding powers of their missiles were to become more directly visible. No healthy human being could find pleasure in tearing with his finger the intestines out of a hare, and listening to its penetrating death cry.

There is, however, one circumstance which, if it arises, extinguishes all our instinctual inhibitions against killing. Any trace of pity disappears instantly if we are in serious fear of the attacking animal — or human. Such fear may momentarily prevent the outbreak of aggression, but the aggression itself will be increased, not reduced.

SELF-ANNIHILATION

In retrospect, we want to look again at the peculiarities and limitations of the killing-inhibition among social animals, to see clearly how closely related these phenomena are to our nonrational inhibiting mechanisms. It is from that vantage point that we want to consider the threat of self-annihilation that hangs over mankind.

We understand now how revolutionary and dangerous the invention of the first weapon, the hand axe, must have been. It destroyed forever the functional equilibrium between aggressive instinct and its inhibiting restraint. If one visualizes how the sudden anger and aggression of an armed anthropoid could transform itself into murder, one may indeed wonder why mankind did not perish immediately after it had invented its first tool.

Modern warfare, with its impersonal methods of killing that operate at ever-increasing distances, is eliminating our instinctual restraint to kill, because quite literally it has removed every single one of the factors that stimulate the killing inhibition. The airplane bombardier who pushes the button that releases the bombs receives no stimulus whatsoever that could make him sense the consequences of his action.

Moreover, psychoanalysis is probably correct in its belief that man is full of frustrated aggressive instincts and can explode any time, quite unexpectedly and devastatingly. I do not think Freud's notion of the death instinct, that opposes the creative eros, is correct, but there is indeed the possibility that the evolutionary process in grey antiquity bred into us an excess of aggression. In our day, with its changed ecological conditions, this excess has become a serious danger to mankind.

If one therefore looks with the eyes of an animal psychologist at the situation of the species "homo sapiens," one might well despair and predict for ourselves an early and horrible ending. Our only hope lies in our power to think and in the moral resolutions that we may achieve with the help of that power. That power is probably also the reason that mankind was not destroyed by its very first weapon; an irresponsible animal species could not have invented such a weapon in the first place. The exploratory behavior which unconditionally must precede any such invention has, for its prerequisite, a function which, as Baumgarten has pointed out, is closely akin to that of posing a question and receiving an answer. It is only toolmaking man who is able to take into account the sucess of what he is doing. In driving in a nail, every stroke of the hammer is governed by the feedback of the effect of the preceding one — in a manner of speaking, by the answer which the object has given to the act of the working human. We know that this way of acting, which is regulated by the feedback of its own sucess, is exclusively human and closely related to language. This faculty is tied to the so-called Praxis-Gnosis-center which is in close proximity to the speech center in the human frontal lobe. As Heinrich Kluver has shown, not even the anthropoids, zoologically our closest relatives, possess anything like this part of the human brain and indeed no animal has such capabilities. In other words, the inventor of the first weapon could not have been an irresponsible animal. He had to be a member of the species homo sapiens, who is at least in principle able to govern his actions through rational responsibility. Kant's categorical imperative, addressing itself to the possibility of elevating the maxims of one's own actions to general laws of nature, questioning whether this would result in a rational impossibility, merely describes, if translated into the pragmatic biological, the essence of purposeful activity.

We connect the social instincts and inhibitions with the highest achievement of moral responsibility. It is thus sometimes difficult for us to determine whether the command that drives us to commit certain acts originates in the deepest pre-human layers of our personality, or whether it is the result of our highest ability — the power to reason. Since we have been trained from early youth to put a very high value on the latter, and a very low one on the former, we are inclined to accept as the result of our rationality what is, in fact, no more than the result of sound instincts. Since both have the same function, there is a surprising similarity between behavior that is generated by instinctual sources, and behavior that is generated by our culture-bound moral responsibility. The absolute inhibition that keeps a male hamster or dog or some other mammal from biting a female of its species leads to behavior forms that are forceful reminders of the centuries-old Western custom that commands men to behave chivalrously toward females. Under conditions of captivity which make flight impossible, the female hamster can literally bite to death the much stronger male, because the male is utterly incapable of making even the slightest effort to defend himself. In the same manner, the highly ritualized duels of the cichlids are reminiscent, as we pointed out, of the many forms under which human duels are fought according to firmly observed rules. This is why one cichlid, cichlasoma diocellatum, which engages in a particularly stylized form of duel, has been nicknamed in America Jack Dempsey, a fighter famous for the fairness and elegance of his boxing.

WHAT DIRECTIONS?

But where do all these insights into animal behavior and our inferences to human behavior lead us? What can we possibly do to strengthen man's killing inhibitions? I am afraid that at this point my answers will be as commonplace for the moralist as what I have said about species preservation is commonplace for the biologist. The most obvious first step must be, I think, to intensify the contacts of all men with each other and to make these contacts as personal as possible. The war propagandists of all times — unfortunately they always have had a better working knowledge of human instincts than the philosophers of humanity — know quite well that the best way to eliminate inhibitions to kill the enemy is to persuade their people that the enemy is very different from them. Zoologically speaking, these propagandists try to make us believe that the enemy belongs to a different species. The great military successes of the Zulu undoubtedly derived in part from the fact that Zulu means simply "human" and the Zulus were therefore quite convinced that all non-Zulus were non-human. All national isolation, all racist propaganda rests on this principle. But once we have had some close personal contact with the "enemy," we know how small, in the last analysis, the differences are between him and us, and the better we know him the more we will hesitate to take part in his destruction.

I regret that I have no other advice at this point. We really know very little about the causal connections of human social or asocial behavior. All I have tried to do is to infer from certain analogies at least the direction in which we must seek if we want to find a remedy. It is the hope of enticing others to think about these problems, if only by contradicting me, that has moved me to draw attention to these analogies between human and animal behavior.

I have no doubt that some moralists will tell me that any attempt to find physiological reasons why men will engage in intraspecific mass homocide is nonsense to begin with. Human behavior in general, and particularly social behavior, is never physiologically determined but depends entirely on man's responsible reasoning and the decisions of his "free will." I am far from denying the existence of all these exalted sentiments and resources. I only entertain some doubts as to their immediate influence on collective human behavior. This doubt is supported by grave reasons. One must begin by seeing how gigantic the achievements of man are in controlling and adapting to his physical surroundings. He has achieved this exclusively through his faculty of conceptual thought, his syntactic language — in other words by functions which only he possesses and which animals lack completely.

Looked at in this fashion, the "master of the universe" would really seem to be exempt from the physiological rules and laws that govern the animal kingdom. Comparison with it must seem blasphemous. But the comparison will seem less offensive if instead we look at men's stupendous failure to control his behavior toward members of his own species. While he has moved over the millennia to a position where he dominates the earth, considered collectively as species he has not made the smallest progress toward mastering himself. This in spite of the fact that all over the globe and throughout time, prophets and priests and wise men have tried to imbue us with a responsible morality and love of mankind. And this is not all. Many an effort has been made in the course of history to put love of mankind and rational morals on the very throne of the state, asking that it rule mankind. All these efforts eventually came to nought and were flushed away by the dark strength of irrational behavior, lust for power, aggression, territorial expansion, and so on endlessly — all motives that are not specifically human but characteristic of all higher animals. We have to face the bitter fact that we humans, looked at collectively, act, in our intraspecific social behavior, not unlike rats. The tendency of rats to foment partisanship, and to overpopulate their limited living space, coupled with their self-annihilating battles that result from these two causes, form an evil simile to human society.

OUR BEST HOPE

These remarks are by no means prompted by a hopeless fatalism, nor are they the expression of some cynical materialism. It is exactly because the most dangerous adversaries of a rational human society derive their strength from the instinctual — the level that is not yet specifically human — that our best hope is to learn to understand its causal structure. Nor does the conviction that the pathologic disturbances of our social life are causally determined deny the existence of the higher human values. The notions of purpose and of causality not only do not contradict each other, but are meaningful only if considered jointly. The most beautiful moralistic convictions about what course a chain of events ought to take give us only little power to set the events on this course. Any insight into their causal connections must greatly enhance our abilities to determine their outcome. Any attempt to achieve moral goals without insight into the causal structure is overwhelmingly likely to remain powerless. And causal insights without moral purpose are meaningless.

Science has been responsible for our progress, but part of what it has given us are the very weapons that today threaten us with self-annihilation. It is high time for science to explore the nature of this most burning threat. Until now — not too successfully — only the moralists have tried their hand. Let us apply our scientific curiosity to the task of how we can strengthen the instinctual inhibitions that must help us if we are to avert destruction. Perhaps ethology can make a contribution.

Trinity + 25

Eighteen views of the Atomic Age by the men and women who took part in launching and developing it are presented in our Twenty-Fifth Anniversary issue

NOW IT HAS BEEN TOLD BY

EUGENE RABINOWITCH, GLENN T. SEABORG, ALICE K. SMITH, LT. GEN. LESLIE R. GROVES, LAURA FERMI, R. R. WILSON, RYUKICHI IMAI, SIR RUDOLPH E. PEIERLS, L. A. ARTSIMOVICH, SIGVARD EKLUND, J. GUERON, ALVIN M. WEINBERG, E. CREUTZ, GERALD W. JOHNSON, ROBERT E. MARSHAK, HANS A. BETHE, RALPH E. LAPP, DAVID H. FRISCH

Don't miss this Historic Double Issue. Copies are still available in bulk at special rates. Address orders to:

Circulation Manager
BULLETIN OF THE ATOMIC SCIENTISTS
935 E. Sixtieth St., Chicago, Illinois 60637

Please send me .... copies of Trinity +25 The Special Anniversary Issue of the BULLETIN OF THE ATOMIC SCIENTISTS

NAME ....

STREET ....

CITY .... STATE .... ZIP ....

Price List: Single Copies, $1.35; 10 to 50, $1.10; 51 to 200, $.90, More Than 200, $.78

☐ Check Enclosed ☐ Please Bill Me

Definitely Top Drawer

Chicago's Fall Paperbacks

COLLEGE CURRICULUM AND STUDENT PROTEST
Joseph J. Schwab
P366 $2.95

THE SOCIAL ORDER OF THE SLUM *Ethnicity and Territory in the Inner City*
Gerald D. Suttles
P363 $2.45

THE RISE OF THE WEST
A History of the Human Community
William H. McNeill
P385 $4.25

CHINA IN CRISIS
Volume One, Books One and Two: *China's Heritage and the Communist Political System*
Edited by **Ping-ti Ho** and **Tang Tsou**
Volume Two. *China's Policies in Asia and America's Alternatives*
Edited by **Tang Tsou**
Vol. 1, Book 1 P353 $3.95
Vol. 1, Book 2 P354 $3.45
Vol. 2 P355 $3.95

AMERICAN DIPLOMACY
1900-1950
George F. Kennan
P367 $1.95

SIR THOMAS BROWNE
Selected Writings
Edited by **Sir Geoffrey Keynes**
P347 $3.25

GIRAUDOUX
Three Faces of Destiny
Robert Cohen
P371 $2.45

CHEKHOV: A BIOGRAPHY
Ernest J. Simmons
P372 $3.95

VICTORIAN PEOPLE
A Reassessment of Persons and Themes 1851-1867
Asa Briggs
Revised Edition P365 $2.45

TO THE ARCTIC! *The Story of Northern Exploration from Earliest Times to the Present*
Jeannette Mirsky
P376 $3.45

THE WESTWARD CROSSINGS: BALBOA, MACKENZIE, LEWIS AND CLARK
Jeannette Mirsky
P370 $3.45

A REFERENCE GUIDE TO ENGLISH STUDIES
Compiled by **DONALD F. BOND**
Second Edition P83 $1.95

PERSPECTIVES IN LINGUISTICS
John T. Waterman
Second Edition P106 $1.95

THOUGHT IN THE YOUNG CHILD
Edited by **William Kessen** and **Clementina Kuhlman**
P382 $2.95

New in the Heritage of Sociology Series

CHICAGO SOCIOLOGY: *1920-1932*
Robert E. L. Faris With a Foreword by **Morris Janowitz**
P379 $2.75

INTRODUCTION TO THE SCIENCE OF SOCIOLOGY
Including an Index to Basic Sociological Concepts
Robert E. Park and **Ernest W. Burgess** Abridged and with a New Preface by **Morris Janowitz**
Student Edition P380 $4.75

THE NATURAL HISTORY OF REVOLUTION
Lyford P. Edwards With a Foreword by **Morris Janowitz**
P386 $2.25

The University of Chicago Press
Chicago, Illinois 60637